MODERN LIFE SCIENCE

FITZPATRICK · HOLE

THE HOLT LIFE SCIENCE PROGRAM

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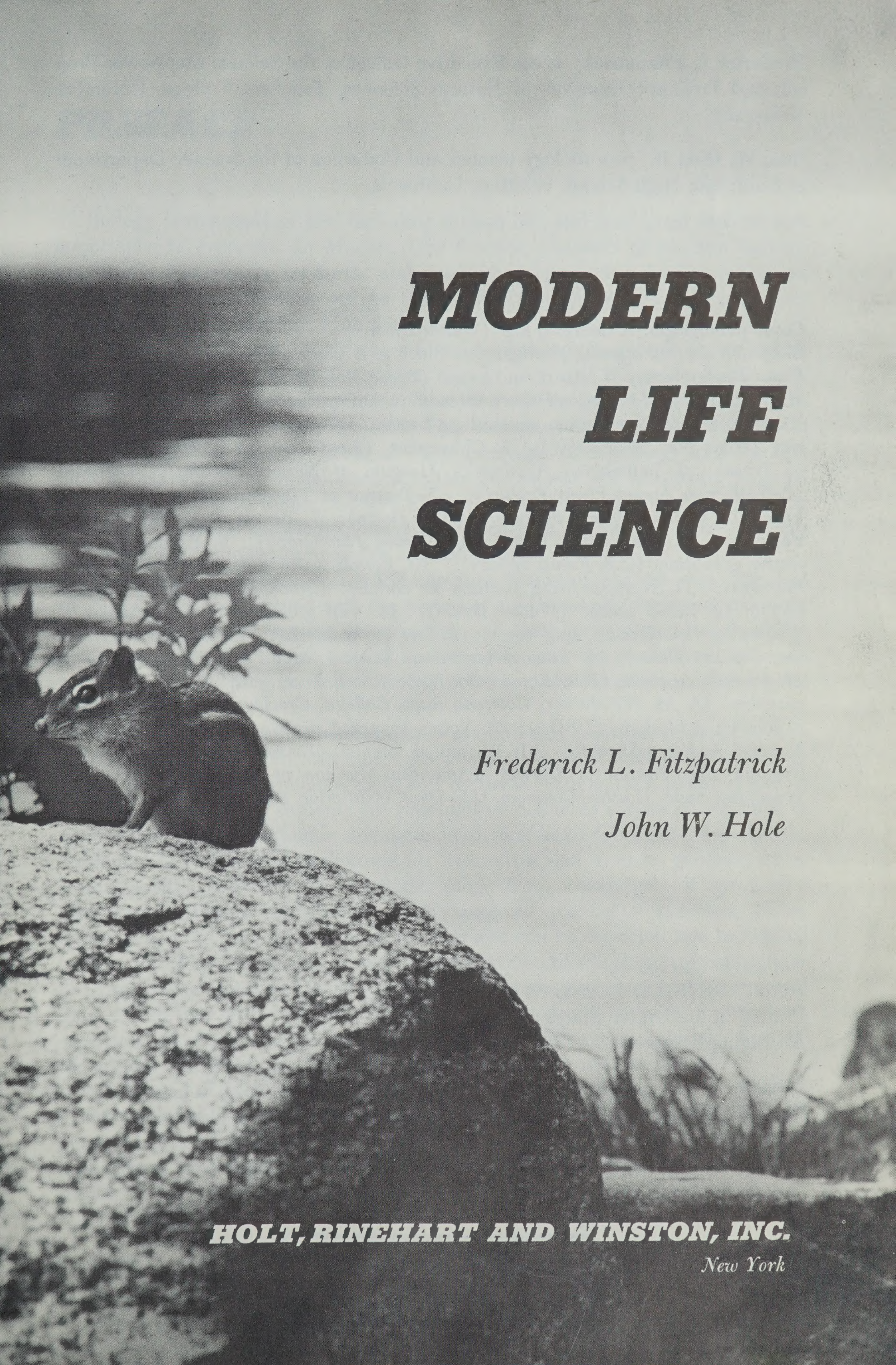
MODERN LIFE SCIENCE



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Cover photograph: A decaying log. (*Walter Dawn*)
Block and chapter opening photographs: Block 1. A pond scene. (*Leon Harmon from* Photo Researchers); II. An ocean scene. (*Bruce Roberts from Rapho-Guillumette*); III. Hopi indian dwellings of the southwestern U.S. (*American Museum of Natural History*); IV. An aggregation of whirligig beetles. (*Walter Dawn*). Chapter 1. Field trip. (*Hays from Monkmeyer*); 2. Chloroplast. (*Plant Research Institute, University of Texas*); 3. Radiolarian. (*American Museum of Natural History*); 4. Hydra. (*Perkins from Annan Photo Features*); 5. Portrait of Linnaeus. (*New York Public Library*); 6. Desmids and diatoms. (*Walter Dawn*); 7. Beaver dam. (*Annan Photo Features*); 8. The Trieste. (*Official U.S. Navy Photograph*); 9. Example of protective coloration. (*U.S. Forest Service*); 10. Beaver washing its face. (*Annan Photo Features*); 11. Nitrogen-fixing bacteria in nodules. (*Brookhaven National Laboratory*); 12. Blood smear. (*Walter Dawn*); 13. Villi greatly enlarged. (*Robert F. Waldeck*); 14. Human lung tissue. (*Robert F. Waldeck*); 15. Human nerve tissue. (*Walter Dawn*); 16. Tetanus bacterium. (*Drs. S. Mudd and T. F. Anderson*); 17. Penicillium mold. (*Russ Kinne from Photo Researchers*); 18. Grasshopper chromosomes. (*A. M. Winchester, Colorado State College, Greeley, Colorado*); 19. Bee pollinating a blossom. (*USDA*); 20. Young snapping turtle. (*Lynwood Chace from National Audubon Society*), 21. Portrait of Mendel. (*American Museum of Natural History*); 22. Portrait of Darwin. (*American Museum of Natural History*); 23. Whooping crane. (*Luther Goldman, U.S. Dept. of Interior, Fish and Wildlife Service*).

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PREFACE

Biology is the study of life, including human life, and is of great interest and importance to everyone. In *Modern Life Science,* concepts of modern biology are simply and clearly set forth, and provision is made for a wide variety of student activities which encourage the learner to discover his own evidences and to make generalizations from them.

Modern Life Science approaches the study of living things from an ecological point of view. The individual organism is seen as one of the many factors in a complex and changing environment. The interrelationships between organisms and their environments are discussed. This ecological theme allows students to proceed from the familiar world of their everyday surroundings into the less familiar aspects of biological science. Although the text and laboratory program support an ecological theme, modern ideas about cell structure and function are introduced. Newer knowledge about microstructure as well as basic concepts relative to the chemical basis of life are also treated.

Modern Life Science is divided into four blocks of content area. The first of these blocks is concerned with the *nature of organisms and their environments;* the second deals with *natural communities and their populations;* the third describes *man and his role in natural communities;* and the final block takes up *problems of population increase, heredity, selection, and the wise use of biological resources.*

Early in the program, the biologist is presented as a scientist who is curious about living things, who asks questions about them, and who seeks to answer these questions with available tools and methods. Within each chapter, and at the end of each block, students are provided with a wide variety of activities to supplement the topics under discussion with first-hand laboratory experiences. Students are encouraged to discover for themselves and to make generalizations from available evidence. The activities range from illustrations of specialized laboratory technique to student involvement in qualitative exercises. Other activities require quantitative measurements and can be extended into individual or group projects. At the end of each of the first two blocks there are instructions for detailed ecological studies of pond and land communities which involve several days of full-time field and laboratory work. These studies require observations, recording of data, analysis of data, and use of reference materials. Specific techniques and ideas developed in earlier chapters are also employed.

At the end of each chapter there is a test of *Word Meanings* and a *Self Test.* These tests should be used by the student as a check on his understanding of the chapter materials. The tests are followed by *Discussion Questions, Things to Do,* and a list of recommended reference books for the further exploration of various topics.

The authors wish to express their appreciation to Mr. James G. Brown, Science

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BLOCK I

The Simple and the Complex

The organized study of living things did not begin until the third century before the birth of Christ. At this time the philosopher and scientist, Aristotle, established the Lyceum, a famous school of ancient Greece. Aristotle wrote about the living things he observed, and suggested a method of classifying them. Another resident of ancient Greece, Theophrastus, began to pay special attention to the study of plants. At the time plants were of special interest because they were the sources of various medicines. Though Aristotle and his followers made many mistakes, they were the first to undertake a systematic study of nature.

The ancient Greeks, however, had no microscopes or magnifying glasses. They could only observe things they could see with the unaided eye. And so a whole universe of tiny living things was unknown to them. This state of affairs persisted for centuries. Then in the eleventh or twelfth century, lenses that would magnify small objects were discovered. Even so, many more years passed before men learned to make microscopes.

A microscope is more than a simple magnifier, because it uses a combination of lenses. Early in the seventeenth century the first microscopes were being tried out, and in the hands of an Englishman named Hooke, one of these early microscopes helped to make history. Hooke saw and described cells in a slice of cork tissue. Meanwhile, across the English Channel in Holland, a Dutchman named Leeuwenhoek began to study all sorts of minute plants and animals that he found in samples of water.

Great improvements have been made in microscopes since Hooke's day. During the past 30 years a new type of magnifier known as the electron microscope has been developed. This microscope has no glass lenses. Instead, it uses electrical devices to magnify and focus images on a screen. An electron microscope can magnify objects as much as 300,000 times. Then you can photograph the magnified image, and magnify the photograph even more.

The electron microscope has been of great value in man's study of cell structure and function. Of course, you will not find it in most school laboratories. But you can still profit by studying electron microscope photographs.

CHAPTER 1

Environment and Life

Wherever you may live, you are surrounded by ***organisms*** (*or*-gan-*izms*). What are these organisms? They are the plants and animals of our world. Some of them are very well known to you. Others are so small that you are not likely to notice them. Many of these small organisms exist in untold numbers. But even the smallest have that remarkable spark of life that sets them apart from the rocks, soils, and other nonliving things.

FIELD OBSERVATIONS

One way to learn more about organisms is to observe them in their natural surroundings. Let us imagine that we are going on a field trip in the early autumn. We wish to take a good look at the organisms and their ***environment*** (en-*vih*-run-munt) or surroundings. We take a digging tool and several widemouth bottles with us, so that we can collect a few specimens and bring them back to the classroom for study.

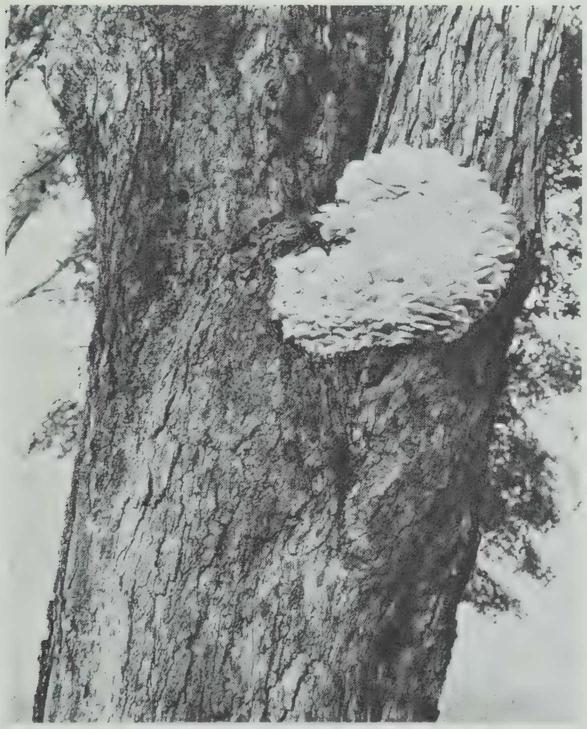
Features of the environment. As we go down a lane between a meadow and a field of grain, we see many plants all around us. The grain is a *cultivated plant;* one that is grown to provide food and other useful materials. In the meadow are various other plants, including grasses, weeds, and perhaps a few bushes and trees. These are all *green plants,* and they can make their own food. But we may also see some *nongreen plants,* that cannot produce food. Some of these nongreen plants are ***fungi*** (*fun*-jye), a group that includes the *mushrooms.* The *shelf fungi* shown in Fig. 1–3 are also in this group.

Here and there we may see insects in the air, on the path we are following, or on some of the plants. Birds may be flying about nearby. And all around us, even in the dust at our feet, are plants and animals so tiny that we are not aware of their presence.

The plants and animals that surround us, wherever we may be, are a part of our environment. They are the

1–1. A fall field trip will awaken us to our changing environment. (*U.S. Forest Service*)

1–2. Strawberries are a popular cultivated crop. (*Munroe from Photo Researchers*)



1–3. Shelf fungi, a common nongreen plant. (*USDA*)

1–4. Name all the living and nonliving things in this picture. (*Grant Heilman*)

living factors of this environment. But there are many other factors of any environment that are *nonliving.* For instance, there is the air that we breathe.

Air is a mixture of gases, including nitrogen, oxygen, and carbon dioxide. All of these gases are related to the welfare of living things. Other nonliving factors in the environment are sunlight and temperature. If the sun is shining brightly, the air may be warm, and we may be comfortable although we are lightly dressed. On the other hand, the sun may be hidden by clouds, and there may be a definite chill in the air. You know from experience that such factors affect your comfort and well being. They have similar effects upon other organisms. You will find an experiment that shows one effect of temperature change on page 17 of this book.

Sunlight is very important to green plants. Sunlight provides the energy these plants need to make foods. See page 122 for an experiment which shows how necessary sunlight is in the lives of green plants.

The soil is another feature of the land environment. A type of soil called *gravel* is made up of small pieces of rock. *Sand* is similar to gravel, except that the rock pieces are smaller. *Clay* consists of exceedingly small particles that are left behind when certain kinds of rocks disintegrate. When gravel, sand, clay, and the remains of plants and animals are mixed together, the result is a soil called *loam.* Loam is the soil of some of our most fertile fields and gardens.

1–5. What are the differences between the plant grown in sunlight and the plant grown in darkness? (*Grant Heilman*)

1–6. A beautiful tulip garden grown on loam soil. (*Grant Heilman*)

Water is also a significant factor in any environment. On any trip out of doors you are likely to see a small stream or pond. The stream and pond both contain fresh water, which is water with little or no salt in it. Many plants and animals live in freshwater ponds, streams, and lakes.

You should know that fresh water is not limited to the sources mentioned above. The soil may contain considerable amounts of *ground water,* which is water that has seeped down into the ground following rains. There is also moisture in the air around us. The importance of water supplies is very great, because water is essential to life.

You can now see that a number of *physical factors* are a part of any environment. These factors include air, sunlight, temperature, soil, and water. To a greater or lesser extent, the combination of these factors determines what kinds of organisms can survive in a particular place.

Changes in the environment. You are probably aware that changes take place in any environment. You may have noted that running water has washed away the soil in a certain place. You may have noticed plants and animals that have died and are decaying. Perhaps you have seen newly sprouted plants and very young animals. These observations make it clear that changes are always in progress. From hour to hour the plant and animal populations

1–7. This pond is the home of many small organisms. (*USDA*)

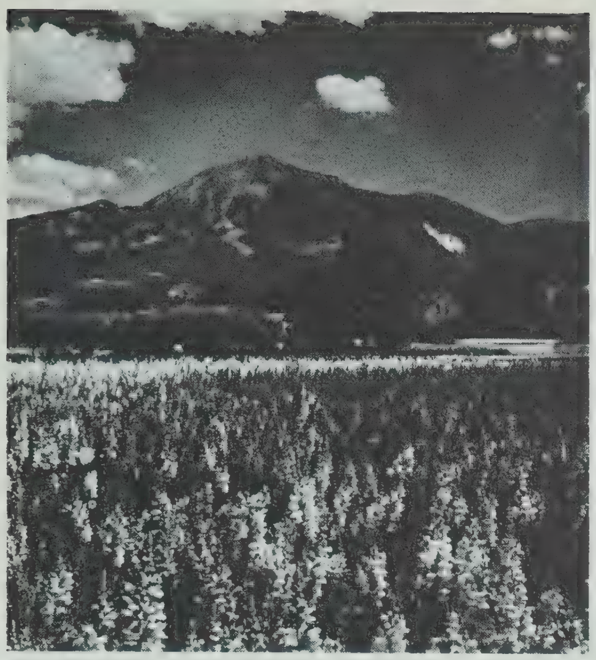
1–8. A forest fire caused this drastic environmental change. How do you think the plant and animal life was affected? (*U.S. Forest Service*)

change, and the physical conditions change also.

Let us assume that it is autumn, which means that winter is on the way. Soon temperatures will fall and snow may blanket the earth. Many of our familiar birds will migrate to southern lands. Frogs will take refuge in the mud on the bottoms of ponds. Woodchucks will remain underground in their burrows. But some animals are unable to escape from the oncoming cold. Most of the insects that you see in autumn are likely to die, but they leave eggs behind them that will hatch in the spring. A good many plants die also, but they may have produced seeds from which new plants will grow. Other plants including the common trees survive, but their life activities are carried on at a *reduced rate* during the cold season.

When the warm, spring days come, there is a rebirth of life. Seeds begin to sprout and eggs begin to hatch. Many living things that were not in evidence during the cold months reappear. Green plants begin to make food in abundance, and as a result, there is much more for animals to eat. Finding food is necessary if animal populations are to prosper. Where food is abundant, animals are likely to be present in large numbers.

1–9. This grey squirrel prepares for winter. (*Rue from Monkmeyer*)



1–10. Springs brings a rebirth of life. (*Grant Heilman*)

We see these *seasonal* changes in the environment occurring year after year. There are also *long-term* changes that are not related to the seasons. At various times in the distant past, the ground you walk on today may have been covered by a sea. At other times it may have been buried under the ice of a glacial period. The hills about you are by no means everlasting, because running water and other forces will eventually wear them away. The one thing that you can count on is that the environment is constantly changing.

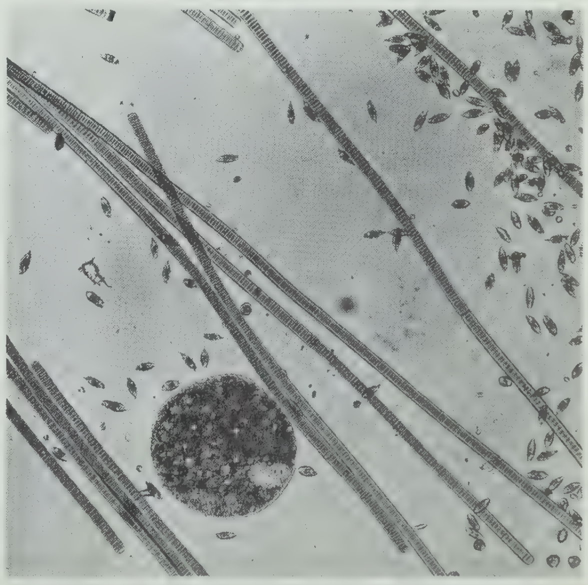
A POND ENVIRONMENT

No doubt the plants and animals of land environments are best known to you. The number and variety of organisms that live in the water may come as a surprise. Among them are many very small types that can only be seen by using a microscope. There are other types that are small, but visible. And there are animals like the frogs, fishes, and turtles, some of which are quite large. These organisms are ***aquatic*** (uh-*quat*-ik), which means that they live in a water environment.

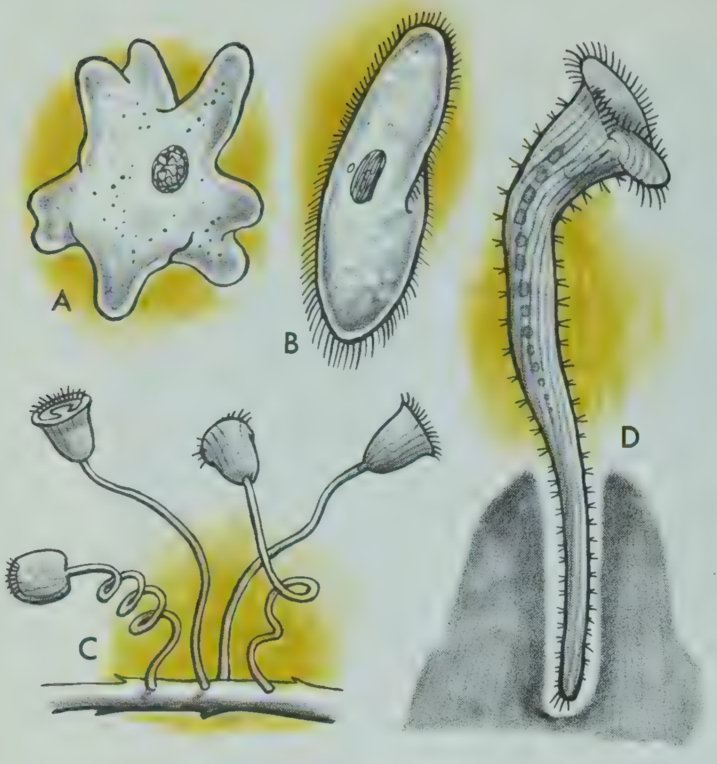
Adaptations for life in the water. Actually, some aquatic organisms can survive for a time on land, especially in moist places. To live in the water, an organism must be *adapted*, or specially fitted for that sort of life. Most plants and animals that live on land lack the necessary adaptations for aquatic life. For example, many land animals breathe air through ***lungs,*** whereas many aquatic animals take oxygen from the water by using ***gills.*** Lungs are adaptations for life on land; gills are adaptations for life in the water.

Aquatic animals. Many of the organisms that live in a pond or stream are small types like those shown in Figs. 1–11 and 1–12. Some are quite simple. Each one has a body consisting of a single ***cell.*** This small unit or cell contains the living substance, which is known as ***protoplasm*** (*pro*-toh-plazm).

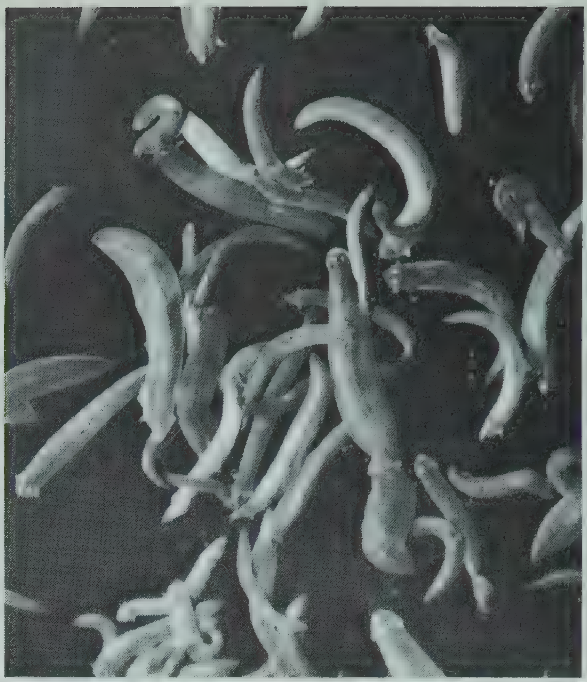
You will also find certain insects in a water environment.



1–11. Some microscopic pond organisms. (*Walter Dawn*)

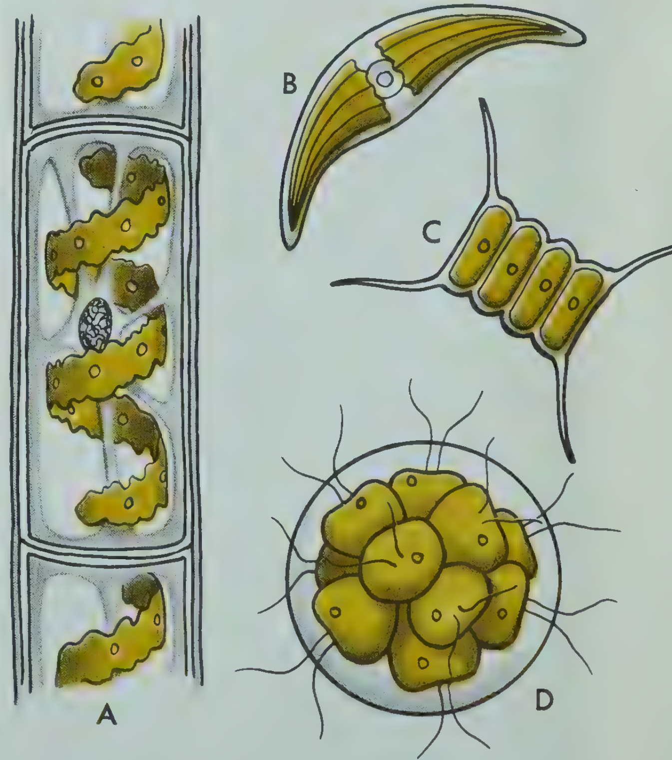


1–12. Protozoans found commonly in pond water: (A) *Ameba,* (B) *Paramecium,* (C) *Vorticella,* and (D) *Stentor.*



1–13. Planaria, a flatworm found in fresh-water ponds and streams. (*Courtesy, General Biological Supply House, Inc., Chicago*)

1–14. A pond scum made up of simple, green plants. (*Walter Dawn*)



1–15. Simple, green plants: (A) *Spirogyra,* (B) *Closterium,* (C) *Scenedesmus,* and (D) *Pandorina.*

Some small, aquatic worms may also be present. You may find these worms in masses of decaying materials that lie near the shore on the bottom of a pond. In the same place there may be various small animals that are relatives of the crayfish. There may also be some pond snails. Insects, worms, crayfish, and snails have bodies made up of many cells.

Aquatic plants. So-called "pond scums" may be seen in summer on the surfaces of many ponds. They actually are simple green plants. If you examine them closely you will see that they are made up of threadlike strands. When you magnify a strand you find that it consists of many cells arranged end to end. These pond scums are simple plants, but they are able to make foods. Like all green plants, they make foods from water and carbon dioxide. Sunlight provides the necessary energy to do the job.

There are also likely to be many single-celled plants in any sample of pond water. Many of these tiny plants are food makers, but some are not. Some small, simple plants that dwell in the water are shown in Fig. 1–15.

A POND CULTURE

Following the instructions on page 109 of this book, collect a pond culture for use in the classroom. Take some time to examine the organisms in drops of water from the culture. Your teacher will help you to do this with the aid of a microscope or projector, as described on pages 112 and 113.

Look for single-celled organisms. Also, look for animals that are many-celled, but in some cases quite small. These animals are likely to be moving about actively. Examine the single-celled and many-celled plants that you may find. Most of these plants do not have swimming motions. They simply float along with the water currents. Make records of your observations in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Do you think it is an advantage for simple, aquatic organisms to move about? Explain your answer.
2. Would you expect to find green plants in the mud and ooze on the bottom of a pond? Give reasons for your answer.
3. Do you think that plant and animal populations in a pond change from day to day? How could you find out?

ENVIRONMENT AND SURVIVAL

You have learned that many organisms die when winter comes. This tells you that the environment must be reasonably *favorable* if organisms are to survive. What does "favorable" mean? Of course, this depends upon the organism. An arctic coast may be favorable to a polar bear, but many other organisms would not be able to exist under arctic conditions.

Changes in a pond culture. You can learn some basic facts about survival from observations of a pond culture. When you first study a culture you may find half a dozen different kinds of plants and animals present in large

1–16. What kinds of organisms would inhabit a grassland environment? (*Grant Heilman*)

numbers. Now suppose you put the culture aside, and do nothing to it except add pond water to keep it from drying out. What will happen?

After a week has passed, you may find that some of the organisms that were abundant the week before have become greatly reduced in numbers. In their place are other organisms that were not especially numerous a short time ago. Clearly, a great change has taken place.

You may be very surprised by this change. But, when the culture is removed from the pond it is put in a *different* environment. The conditions of life are no longer the same. Now there may be either *more* or *less* light. The temperature may be either *higher* or *lower* in the new location. Other physical factors may be altered. Perhaps many eggs that were not noticed in the first examination have hatched into young insects or worms. But above all, the environment changed, some types were no longer favored, and they

1–17. How do you think winter weather has affected the organisms in this pond? (*Thomas Hollyman from Photo Researchers*)

died out. Other types were favored by the new conditions, and they responded by increasing in numbers.

As a matter of fact, similar changes were taking place in the pond from which the culture came. For conditions of life in the pond would not remain the same for any length of time. As these conditions changed, some types of organisms would die out, and other types would become more numerous.

You will learn more about the environment as you read ahead. No doubt you will be interested in how it affects the welfare of living things, and how organisms are adapted to different kinds of environments.

When we study the environment and ways in which it affects living things we are studying biology. Living things also affect the environment, and this is within the realm of biology too. But biology includes many other kinds of studies, as you shall see.

1–18. A field trip enables students to study some of the principles of ecology firsthand. (*Hays from Monkmeyer*)

THE STUDY OF BIOLOGY

Many people have spent a great deal of time studying plants and animals. These people are called ***biologists*** or ***life scientists.*** They are interested in the structures, functions, and habits of organisms. They also study the relationships of organisms to their environments. This is the study of ***ecology*** (e-*kohl*-uh-*jee*).

Biology is a growing science. In the introduction to Block I, you read how men first studied living things many years ago. So you know that biology is not a new science. You might think that everything worth knowing about living things has already been discovered. If you do have any such idea, you are very much mistaken.

There are still many questions about *how* and *why* organisms do various things. For instance, we know that green plants manufacture foods. We also know how some of the steps in this process take place. But some other steps in food making have not yet been revealed. As time goes on we are almost sure to learn more about food making.

Food making is only one example of a process which is not fully understood. There are many others. As more and more knowledge is gained through study and experiments, the science of biology grows. In this respect biology is like any of the other sciences. All of the sciences are changing continually as new explanations are sought and answers are found.

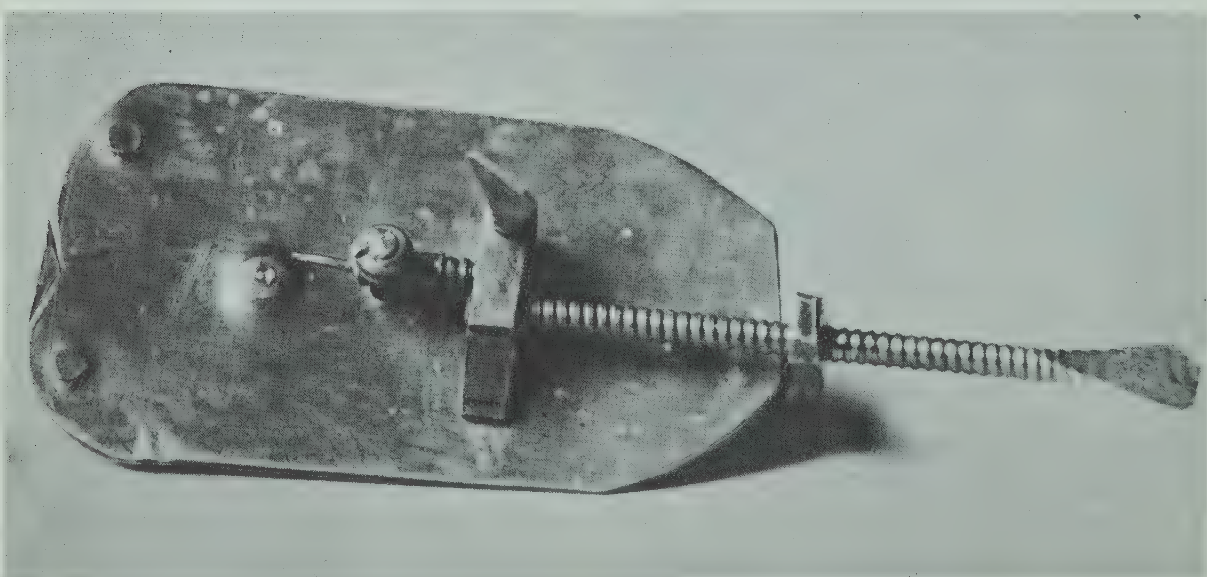
Biology has practical applications. What we do know about living things is of great value in everyday activities.

1–19. A student scientist, Helen Greer, one of the winners of the Science Talent Search. (*Science Service*)

Doctors, druggists, foresters, various government workers, and the men in industry who develop new products depend upon biological knowledge. So do farmers and others who raise the crops from which we obtain foods and the many other materials used in modern life. Even some of our hobbies, such as fishing, hunting, or raising pets, relate to biology. And of course, we need to know the principles of biology so that we can understand the functions of our own bodies.

Methods of the biologist. Through the years biologists have developed methods of studying living things. They have learned to raise various organisms in their laboratories. They also study many of these organisms in their natural environments. Various instruments have been devised to make such studies possible. You have already read about microscopes and electron microscopes, but they are only a part of the story. There are even delicate instruments which make it possible to remove a tiny part from a single cell.

In all of these studies biologists are seeking answers to questions. Sometimes the answers are to be found outside the laboratory. In other cases experiments are planned and carried out entirely in the laboratory. Various methods are employed in these experiments. What is learned, however, either



1–20. The Leeuwenhoek (1632–1723) microscope helped Leeuwenhoek to discover the world of microscopic life. (*University of Utrecht Museum*)

1–21. The electron microscope enables the scientist to study minute cellular structures in detail. (*RCA*)

outside of the laboratory or in the laboratory, always depends upon *observation.* The quality of the results depends on the *accuracy* of these observations.

Making observations and forming conclusions. The good biologist must learn to observe with great care. He must keep accurate records that are made at the time of the observations. In many cases he will call upon others to check his own observations. And he will not "jump to conclusions" until a number of observations have been made that yield the same results.

Even so, there are pitfalls that must be avoided. Our senses enable us to see, feel, hear, smell, and taste. We can usually tell whether something is hot or cold, and whether we are standing up or sitting down. We depend upon our senses when we make observations. But, can we always rely upon what we seem to observe? The following tests, in which you will make observations, will help you to answer this question.

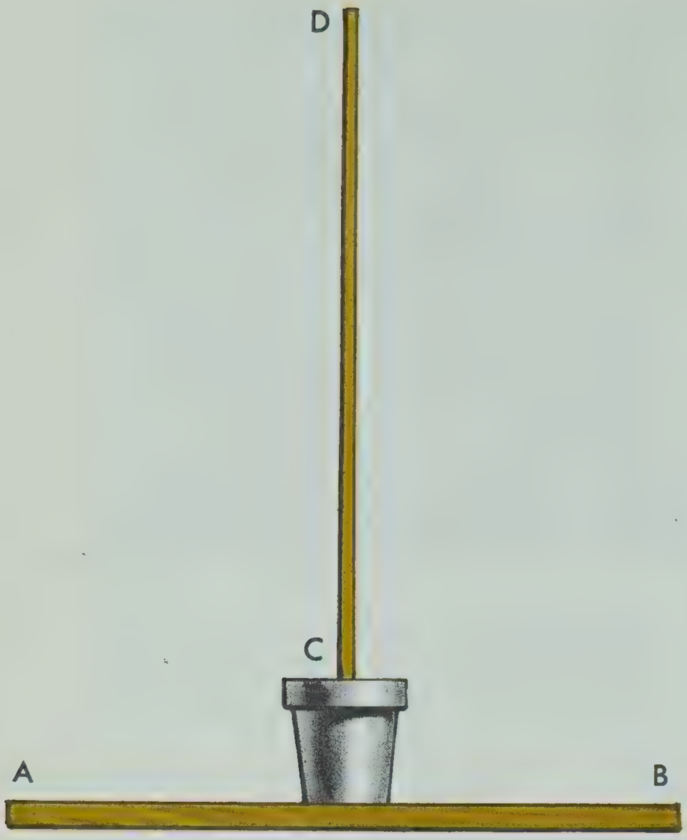
SOME TESTS OF OBSERVATIONS

Sight is the sense we depend on most. Can we always believe what we seem to see? The following three tests relate to this question.

LOOKING AT PRINTED PICTURES Look at the photograph at the top of page 14 of this book. Now look at this same picture through a magnifying lens. You will see that the picture is actually made up of a number of *small dots.* Are the dots closer together in a black area than in a gray area? Examine a gray area with care. What is the shape of a single dot?

AFTERIMAGES Stare at an unshaded white light bulb for about 10 seconds. Now close your eyes and cover them with your hands. Do not press against the eyes; just keep them covered. In a few moments you begin to see what is called an *afterimage.* It is the image of the light bulb. What color is it? Does the color change? How long does the afterimage last?

Later on you will learn more about the nature of color, and how the human eye works. At the moment, however, you may wonder what color the light bulb really is.



1–22. An optical illusion.

ILLUSIONS ABOUT SIZE Now look at Fig. 1–22. Here you see a flower pot resting on a board. The board extends from *A* to *B*. A slender rod has been thrust into the flower pot soil, and you can see the part of it that extends from *C* to *D*.

Now for a question. Is the distance from *C* to *D* shorter or longer than the distance from *A* to *B*? Or, are these distances the same? Take a good look before you decide. How can you test your conclusion? Do so, and see if you were right.

ANALYSIS By this time you may have some doubts about what you appear to see. Here are some additional questions you may try to answer in your notebook.

1. Is the human eye always able to detect the shape of small objects?
2. Scientists use microscopes to aid the sense of sight when they look at small objects. Is there any limit to what can be seen?
3. Did the afterimage of the light bulb have the colors you expected to see? Explain.
4. Is it always easy to judge the relative lengths of different objects? How does a scientist deal with this problem?
5. What can you say about the statement "seeing is believing"?

PLANNING EXPERIMENTS

Experiments are planned to find answers for a variety of questions. A biologist might ask, "What environmental factors affect the sprouting of seeds?" Or, his question might be, "Does heat have any effect on the circulation of blood in an earthworm?"

A multitude of problems. You can see at once that one of these problems deals with plants, and the other one with animals; that one has to do with the sprouting of seeds, and the other with circulation of the blood. So any experiments planned to get answers are likely to employ somewhat different methods. A biologist often deals with a variety of problems, of which the foregoing are only two examples.

The use of references. A first step in answering a question is to find out if answers are already known. After all, the same question may have been asked many times before. If so, experiments may have been carried out, and the results may appear in reference books and journals. Perhaps such results are rather complete and quite satisfactory. Perhaps they give only partial answers. But in any event, they may throw light

upon the types of new experiments that need to be planned.

So the biologist consults references, and finds out what is already known. Then if questions remain, he is ready to plan and carry out experiments. Planning good experiments is not always easy, as you will learn from your own experience.

Preparing for an experiment. In preparing for an experiment, the first step is to decide upon the particular question you wish to answer. Let us assume that you are interested in the circulation of blood in an earthworm. Your general question is, "Does change in environment affect the rate of circulation?"

You have looked for answers to your question in various references, but have found none that satisfy you. So you propose to make some observations of your own. The next job is to assemble the necessary materials. These will include some live earthworms, which you can keep until they are needed in an open jar of moist, but not wet, soil. If you collect your own specimens, you may notice that some of them appear a bit different than others. This need not surprise you because there are about 90 different kinds of earthworms in North America.

In your study of the references you should learn various things about the blood system or *circulatory* system in earthworms. For one thing, an earthworm has red blood. It also has a large blood vessel lying along the top side of its body, just beneath the body wall. This is called the ***dorsal blood vessel.*** Dorsal means on the *back* or *upper* side of the body. Every so often this blood vessel *contracts,* and thus pumps the blood. Keep these facts in mind as you read the next section.

SOME EXPERIMENTS WITH EARTHWORMS

Suppose your first question is, "How often does the dorsal blood vessel of an earthworm contract under normal conditions?" You are going to test one worm at room temperature, and other students will test a number of other worms.

BLOOD VESSEL CONTRACTIONS AT ROOM TEMPERATURE Place a live earthworm on damp paper toweling in a tray. If you look carefully you will see the dorsal blood vessel. When it contracts, it is emptied of blood, and seems to disappear. Then it begins to fill up with blood, and you can see it again.

Count the number of times the blood vessel contracts in one minute. Do this five times, average the results, and enter them in your notebook on a data sheet like the one shown below.

Trial	Contractions Per minute
1	
2	
3	
4	
5	
Average	

Now compare your results with those of other students who have done the same thing. This is important. The worm you used might not be an average worm. You might find that the rate of contraction varies greatly in differ-

Trial	Contractions/min. Room temperature	Contractions/min. 10° below Room temperature
1		
2		
3		
4		
5		
Averages		

ent worms. So when you have the results from many worms they provide one kind of *control.* In order to better understand your results, a control of this type must be considered. There is another kind of control that you will learn about in the next experiment.

CHANGING THE EARTHWORM'S ENVIRONMENT Now change the environment of your earthworm. Put it in a tray and barely cover it with water that is at room temperature. On a page in your notebook make a data sheet like the one shown above.

Obtain five one-minute counts of blood vessel contraction and enter them on your data sheet. Next, use ice cubes to cool some water until it is 10 degrees below room temperature. Barely cover the earthworm with this colder water, and wait until five minutes have passed. Then make five one-minute counts of blood vessel contraction. Enter the results on your data sheet. Average the results of the tests with (*a*) *water at room temperature,* and with (*b*) *water 10 degrees below room temperature.*

In this experiment you used a control. You began with the worm at room temperature. You found out how often the dorsal blood vessel contracted at this temperature. This was your *control figure.* Then you lowered the temperature 10 degrees and got a new figure. You compared the new figure with the control figure. You should also, of course, compare your results with the results of students who used other specimens.

PLANNING AN EXPERIMENT OF YOUR OWN What would happen if you tested a worm in water, and then in weak tea? Would such a change in environment produce a change in blood vessel contraction? Plan an experiment using water and weak tea. Have the water and tea at room temperature. If your teacher approves of the plan, carry out the test, and record the data in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did all of the earthworms in the first test exhibit the same rate of blood vessel contraction? If not, how might the variations be explained? What was the range of variations?
2. Did decrease in temperature affect the rate of blood vessel contraction, and if so, in what way?
3. What would you predict about the rate of blood vessel contraction at 10 degrees above room temperature? Why?

4. Why is it best to make a number of tests, and then determine the average rate?
5. Do you think other changes in the environment might affect the rate of blood vessel contraction? Why?

WORD MEANINGS

On a sheet of paper in your notebook copy the list of words in the first column. Write in the statement from the second column that goes best with each of these words.

1. adapted	Comparing results obtained from many organisms.
2. aquatic	Organisms that live in the water.
3. biology	Adjusted to the conditions of life.
4. cells	The living substance.
5. environment	Everything in your surroundings.
6. fungi	The basic units of structure and function in plants
7. control	and animals.
8. protoplasm	Plants that cannot make food.
	The study of living things.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Ecology is the study of the human body.
2. Circulatory system and blood system refer to the same thing.
3. Environment includes all the things and forces around you.
4. Green plants manufacture their own foods.
5. An afterimage is always the same color as the actual image.
6. You can always tell whether one object is larger than another just by looking at the objects.
7. Mushrooms and their relatives are known as fungi.
8. In biology, you study animals rather than plants.
9. Sunlight and temperature are physical factors of the environment.
10. You are likely to find both plants and animals in a pond culture.

11. Cells are found in plants but not in animals.
12. When you say "organism" you may be talking about a plant, or you may be talking about an animal.

DISCUSSION QUESTIONS

1. How do living things in our environment affect us? How do the physical factors of the environment affect us?
2. In what ways does our environment change during every 24 hour period? Every year? In what ways has our environment changed during the past 10,000 years?
3. In what ways are nongreen plants like animals? How do they differ from animals?
4. You have probably seen water flowing from a spring. Where does this water come from?
5. Suppose you added two or three drops of dilute hydrochloric acid to a culture bowl containing pond organisms. Do you think some of the organisms would be affected? Why?
6. What do you think happens to the tiny plants and animals in a pond that freezes solid in the winter? How sure are you? Plan an experiment that would test your belief.
7. Scientists often spend a great deal of time and energy working on problems that have no immediate practical importance. Why is this type of study worthwhile?
8. What is meant by these statements? (a) "The science of biology is not new." (b) "We still have a great deal to learn about living things."
9. In what ways do you think biologists differ from nonbiologists in their approach to observing nature?
10. What effect do you think iodine solution might have on the tiny animals in a pond culture? How would you set up an experiment to test your belief?
11. What is the best way to find out whether one object is longer than another? Heavier than another?
12. When we use microscopes, are any objects so small that we cannot see them?
13. Is it possible to be mistaken about things you seem to see? How do you know?
14. In what ways are instruments such as the microscope and telescope extensions of the human senses? What other instruments can be called extensions of the senses?
15. What are some of the problems that face a person who wishes to plan a good experiment?
16. How can we tell whether an object is living or nonliving?

THINGS TO DO

1. Collect samples of various kinds of soils. Test each sample by placing it in a jar half filled with water. Shake the closed jar vigorously. Then set it on a table for awhile. The larger particles will settle to the bottom, smaller ones will settle above them, and the smallest will be on top. You can now see how much gravel, sand, and clay is in each sample.
2. Fill a large jar or small aquarium with soil. Pour some water on top of the soil and watch what happens. Leave the jar open and check the water level for two or three days. What does this model show you about ground water?
3. Make a collection of newspaper and magazine articles that describe problems biologists are currently investigating. Display your collection on a bulletin board.
4. Collect a single specimen of some small organism that can be found nearby. Find out all you can about its food habits. Put it on display in the classroom. Be prepared to answer questions that other students may ask. Then return the specimen to where you found it.
5. Look up the "Scientific Method" in various reference books. Report your findings to the class.
6. Select a single organism to observe in detail. Find ways in which it is adapted to the environmental conditions where it usually lives. Report your findings to the class.
7. Select an organism that you can observe several times during a 24-hour period. See if you can discover anything about the organism that may be related to changing environmental conditions. Report your findings to the class.
8. Plan a demonstration to test the effect of freezing temperature on several types of seeds. Be sure to test samples of your seeds beforehand, and assure yourself that most of them are capable of sprouting. (See page 112.) If your teacher approves of the plan, carry out the demonstration.

READING FURTHER

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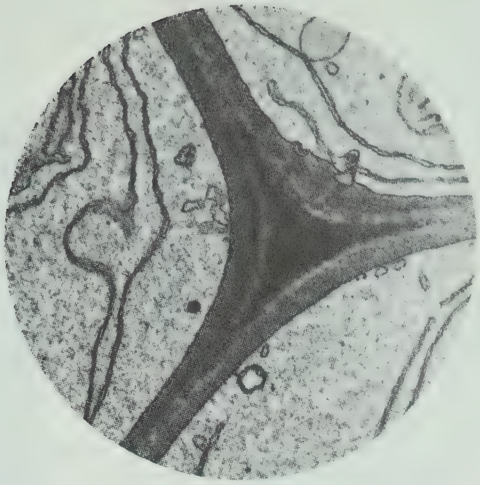
CHAPTER 2



The Living Substance

By this time you may be wondering how living things differ from nonliving things. This is a good question, but it is not one that can be answered easily. To understand the differences, you must know something about the solids, liquids, and gases that make up our world. They are different forms of what we call ***matter.*** Matter is anything that occupies space and has weight.

For instance, solids that you see every day are such things as rocks, trees, cats, dogs, and ice cubes. Liquids are those things that flow. Water, gasoline, molasses, and vinegar are examples of liquids. The air about you is made up of a number of gases. Do not be fooled by gases; they are matter, they occupy space, and they have weight.

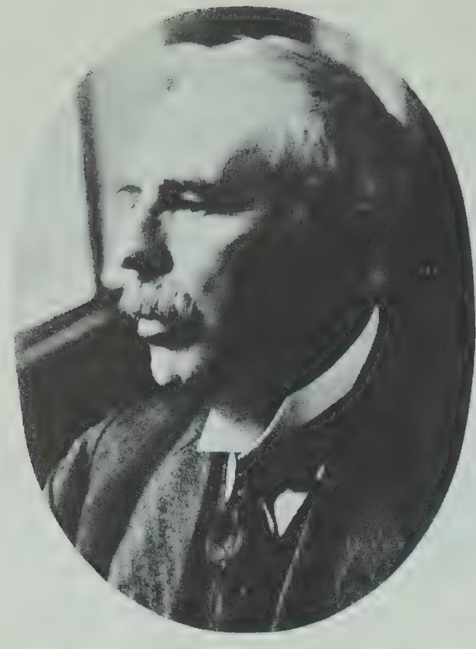
THE ELEMENTS AND THEIR ATOMS

Matter includes all of the substances that we find in living and nonliving things. Your body is made up of matter, and so is a rock out in the field. For the most part, this matter represents different combinations of 92 ***elements*** that exist in our environment. There are some other elements, but they are man-made.

Elements are composed of *similar* units. Thus, a piece of the element lead is made up of very tiny units that are all quite similar, and if the sample is a pure substance, no other units are present. We call these units ***atoms.***

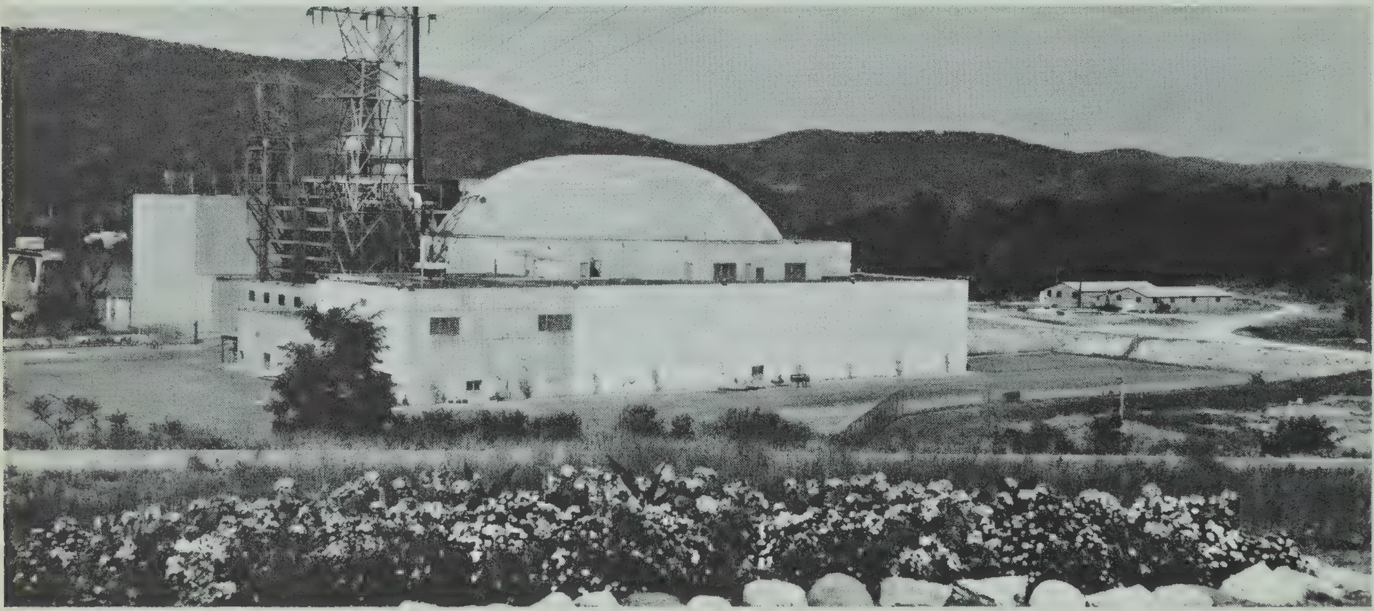
Scientists once thought that atoms could not be changed, but that was before 1919, when Ernest Rutherford, a British physicist, changed an atom of one type into an atom of another type. Since then, scientists have learned to change or split atoms on a large scale. When this is done, vast amounts of energy are released, as in the atomic bomb blast shown in Fig. 2–2.

Small as they are, atoms are not solid. They are made up of even smaller particles. One combination of particles produces a lead atom. A different combination of particles produces an oxy-



2–1. Ernest Rutherford (1871–1937) was one of the early contributors to our understanding of atomic structure. (*Cavendish Laboratory, University of Cambridge*)

2–2. An atomic bomb blast releases a tremendous amount of energy. (*Lookout Mountain Laboratory, USAF*)



2–3. Modern nuclear reactor which generates enough electricity to supply one million persons. (*Consolidated Edison Company of New York, Inc.*)

2–4. Radioactive studies in a biology greenhouse. (*Brookhaven National Laboratory, Upton, Long Island, New York*)

gen atom. Each of the elements has a special combination of particles.

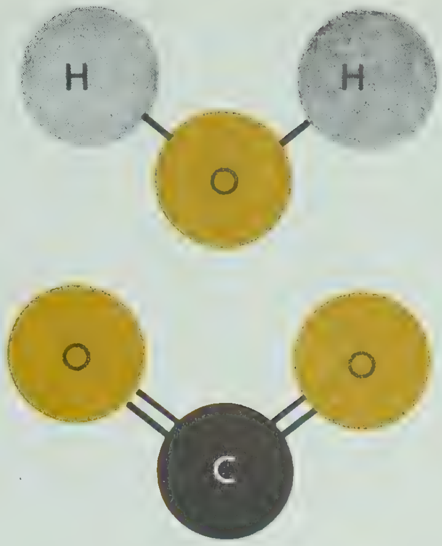
In fact, the same element is often represented in nature by more than one form of atom. The gas hydrogen is one of the common elements. But there are three forms of hydrogen atoms that contain different numbers of particles and have different weights. The most common type is what we call the hydrogen atom. The other two types are called ***isotopes*** (*iso*-topes) of hydrogen. Many other elements have one or more isotopes.

Radioactive atoms. Some atoms are quite *stable;* they tend to remain just as they are. But some atoms are *unstable.* Isotopes are among the atoms that are likely to be unstable. Even when left untouched these unstable atoms give off particles and energy, and become atoms of a different nature, or even atoms of a different element. We say that such atoms are ***radioactive*** (radio-*ak*-tiv), and when they are present in any substance, that substance is radioactive also. Various radioactive substances are used in biological studies.

Gamma rays, for example, represent energy given off by radium atoms. These rays are similar to X rays and can pass through solid substances. Doctors use radium to treat diseases of internal organs. Radium and other radioactive substances are also used in various experiments on plants and animals.

Molecules and compounds. Your body and most of the things about you contain a variety of elements. Usually the atoms of these elements are not free, or separate from other elements, but are combined to form ***compounds.*** When atoms unite to form compounds, we say that they are *bonded* together.

About two-thirds of the matter in your body is made up of the compound water. Water is formed by the bonding of two kinds of atoms: hydrogen atoms and oxygen atoms. We write the formula for water as H_2O. In so doing, we indicate that each unit of water contains two H (hydrogen) atoms, and one O (oxygen) atom. Such a unit, which in this case contains three atoms, is called a ***molecule*** (*mol*-uh-*kule*). A molecule of water is larger than an atom of hydrogen or oxygen, but it is still much too small to see. A water molecule is, in fact, the smallest unit you can have, and still have water. It takes a great many water molecules to make even one drop of water.



2–5. Diagram to show how atoms are bonded to form compounds. (A) represents water, or H_2O, in which an oxygen atom is joined to two hydrogen atoms by single bonds. (B) is carbon dioxide, or CO_2, in which a carbon atom is joined to two oxygen atoms by double bonds.

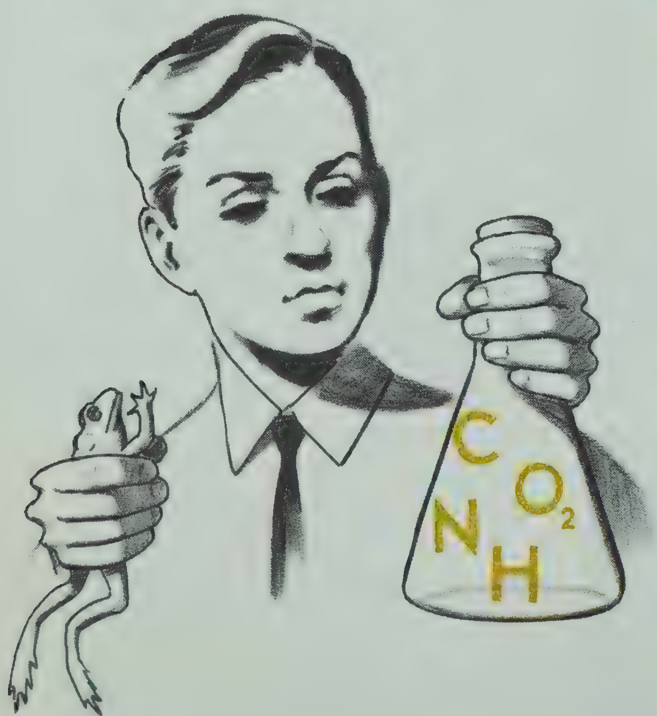
THE NATURE OF PROTOPLASM

In Chapter 1, you learned that cells make up the bodies of plants and animals, and that the living substance in these cells is called protoplasm. You

might think that protoplasm would contain some unusual elements, but such is not the case.

The elements in protoplasm. Four common elements make up about 96 percent of the living substance. These elements are oxygen, carbon, hydrogen, and nitrogen. You can find all of them in nonliving things. So it is not the elements themselves that hold the "secrets of life." Rather, it is the manner in which the atoms of these elements are bonded to form the molecules of compounds. It is the *compounds* of protoplasm that determine what protoplasm can do.

The appearance of protoplasm. What does this living substance look like? You can answer this question by observing many living cells. The protoplasm of some cells is almost transparent. Some parts of protoplasm may be quite fluid. Other parts are more solid and jellylike. In the protoplasm are granules, and various larger structures.



2–6. Do the elements alone hold the "secrets of life"?

Actually, both liquid and solid substances are present.

When you examine protoplasm, you may wonder if the small granules you see are molecules. This is definitely not so. A microscope does not magnify enough to make molecules visible. The granules you see are made up of groups of molecules. Remember, then, that a molecule is exceedingly small, and of course, an atom is even smaller.

Protoplasm does not always look the same. Even in the same cell its appearance varies from time to time. At one time, protoplasm may be quite fluid, and at another time it may appear jellylike. Protoplasm is changing from moment to moment. After all, this is what you should expect since protoplasm is alive.

ELODEA CELLS

You can see samples of protoplasm in the cells of an *Elodea* leaflet. *Elodea* is a water plant that is often raised in aquariums. Cut off the tip of a leaflet, and put it on a microscope slide. Add a drop of water, and cover your specimen with a cover glass, so that it will not dry out. Now focus upon the specimen with a microscope, as described on page 112 of this book. You will see the many cells which combine to make up the leaflet. Change to high power and look carefully at one of these cells.

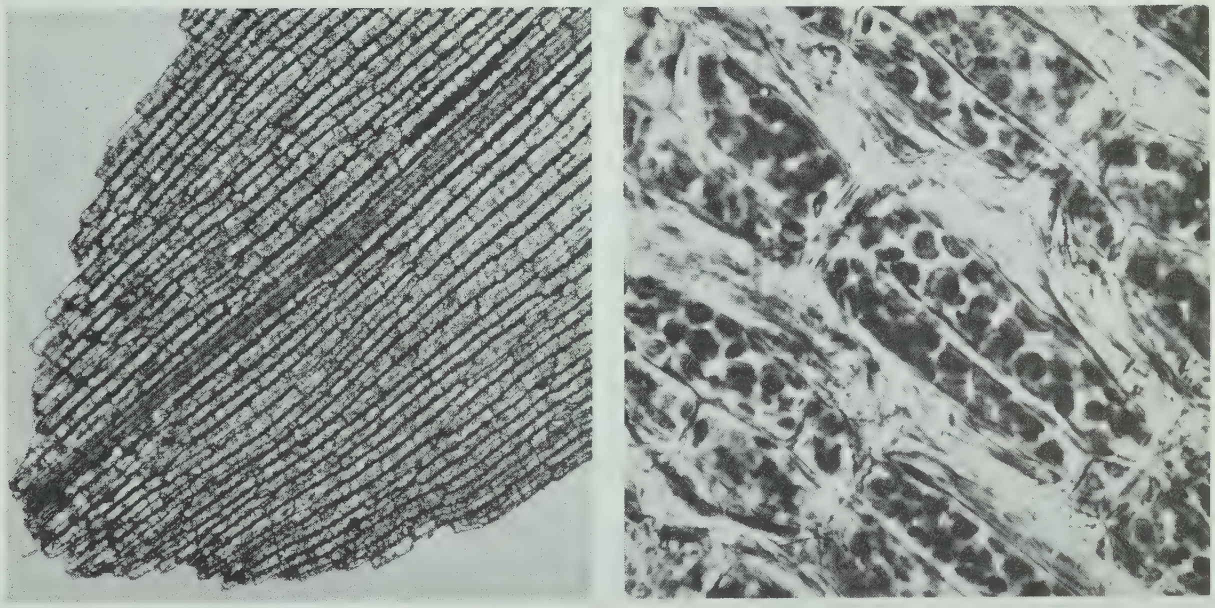
In the *Elodea* cell you see a grayish, but almost transparent material, which makes up the basic cell content. This material is *protoplasm.* Watch it for a

2–7. A chloroplast of a corn cell. (*A. E. Vatter, Ph.D., Courtesy The Upjohn Company*)

time, and you may see that portions of the protoplasm move about. In the protoplasm you may see some small, greenish bodies; they are ***chloroplasts*** (*klor-roh-plasts*), and you find them only in the cells of green plants.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How would you describe the protoplasm in the *Elodea* cells?
2. What makes a leaflet look green?



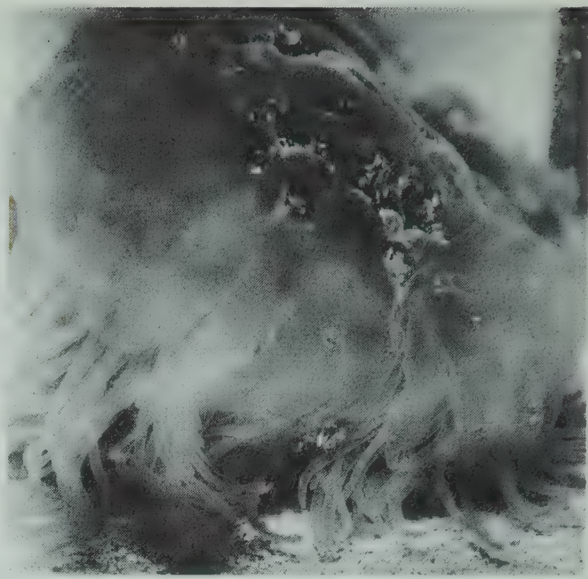
2–8. Two photos of an *Elodea* leaflet. Left-hand photo (magnified 175X) shows detailed cellular structure. Right-hand photo (manified 2000X) shows the individual *Elodea* cells. (*Walter Dawn*)

3. Are all the cells the same size and shape? Explain.

COMPOUNDS OF PROTOPLASM

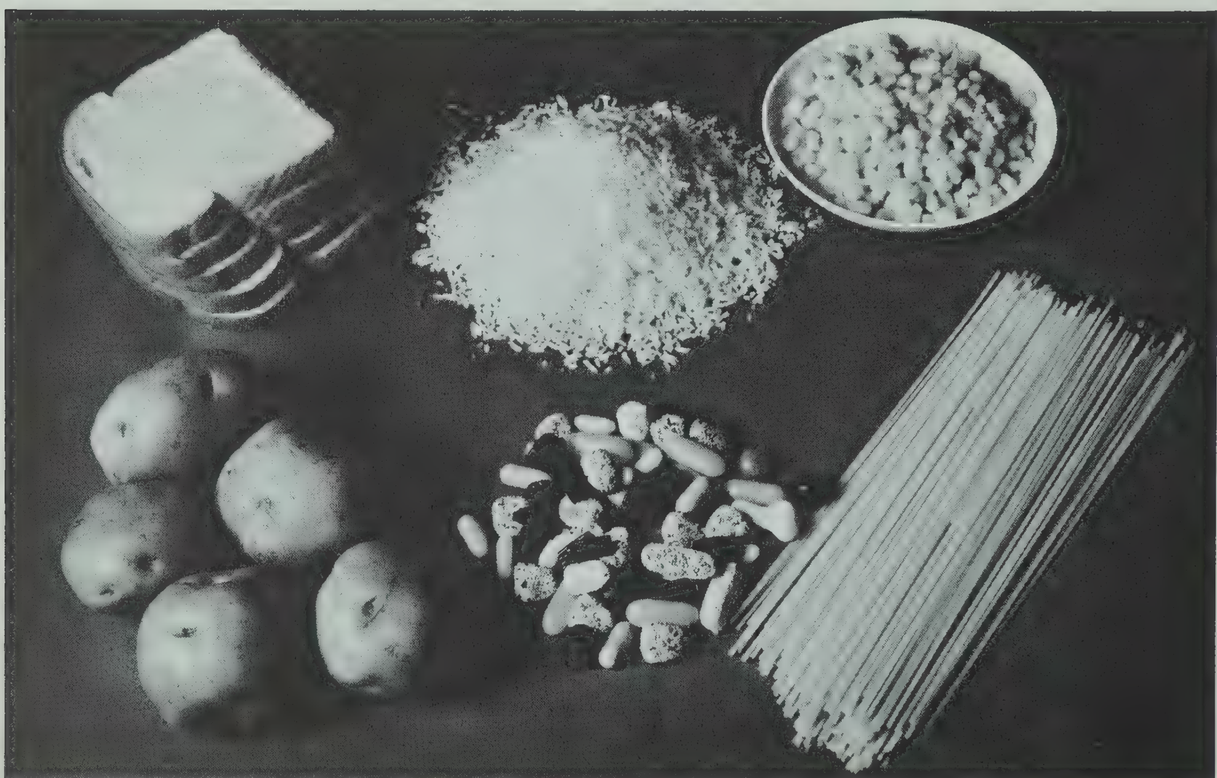
Water. Surprisingly, a large part of protoplasm is water. Some of the simple, aquatic organisms are 96 to 98 percent water. Your own body is more solid, but even so, about 70 percent of your body weight is water. Various salts, including common table salt, are dissolved in this water. As a result, it is not very different from seawater.

The water in protoplasm is necessary for life. Many other compounds are dissolved in it. Its presence makes various changes possible, and without these changes, life could not go on. Even movement of protoplasm depends upon the presence of water.



2–9. This jellyfish is largely made up of water. (*Walter Dawn*)

The carbohydrates. A second group of compounds found in protoplasm includes the *sugars* and *starches*. These compounds contain atoms of three elements: carbon, hydrogen, and oxygen.



2–10. A sampling of some common foods high in carbohydrate content. (*Grant Heilman*)

One simple sugar called ***glucose*** (*gloo*-kose) has the formula $C_6H_{12}O_6$. There are, then, 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen in one molecule of glucose. Table sugar has the formula $C_{12}H_{22}O_{11}$. Our common starch is composed of various groups of $C_6H_{10}O_5$ units.

Compounds like sugars and starches usually have two atoms of hydrogen for every atom of oxygen, which is the same ratio that you find in water. We call these compounds ***carbohydrates*** (*kahr*-boh-*hy*-drayts). Where have you heard this word before? Probably in talking about foods that you commonly eat. Bread and potatoes, for instance, contain a lot of carbohydrate in the form of starch. When you think about the foods you eat, you soon realize that they all come from plant and animal sources. What you really do is eat the protoplasm of plant and animal cells or their products.

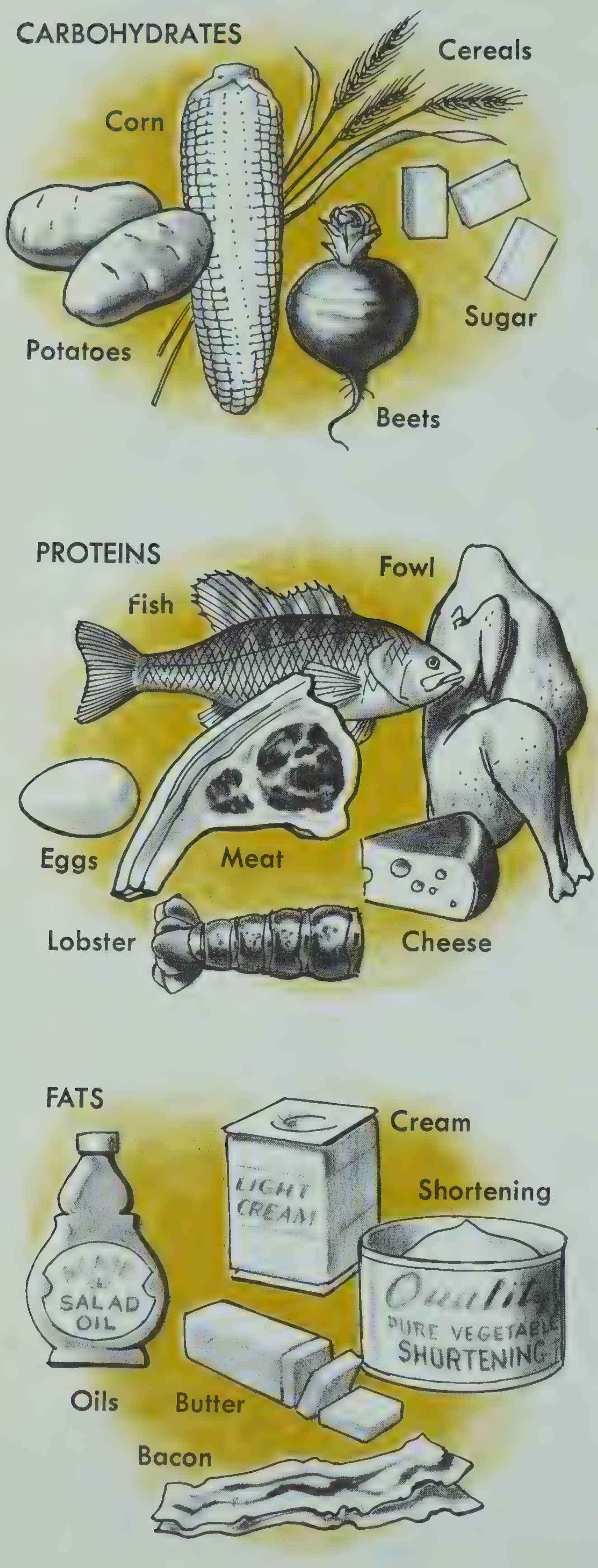
Carbohydrates are a necessary part of the living cell. They are an important source of ***energy***, which is the *capacity* to do work. A cell uses energy in carrying out its life processes. These processes include complex chemical changes. Energy is needed to produce these changes. Both plant and animal cells store carbohydrates.

Fats. Animal cells also contain ***fats***, and plant cells have similar compounds that we call ***plant oils***. Such fat compounds are composed of the elements carbon, hydrogen, and oxygen, but these elements are not in the same proportions as they are in carbohydrates. For example, the formula for one kind of fat molecule is $C_{51}H_{104}O_9$. Thus, the fat molecule contains 51 atoms of carbon, 104 atoms of hydrogen, and 9 atoms of oxygen. You can see right away that the H and O are not in an H_2O ratio, and that the fat contains much less oxygen than you would expect to find in a carbohydrate.

2–11. Which of these foods are high in fat content? (*Aldo Tutino*)

Like carbohydrates, fats are a necessary part of protoplasm. And like the molecules of carbohydrates, fats are often broken down to provide the energy a cell uses in the process of living. You are accustomed to seeing animal fats in the meat that you eat. You have also seen frying or salad oils that came from plant sources. Plant cells store plant oils, and animal cells store fats, and again, these substances serve as energy reserves.

Proteins. A third group of compounds found in protoplasm includes the ***proteins*** (*proh*-tee-uns). Protein molecules are larger and more complex than either carbohydrate or fat molecules. In a protein molecule you find carbon, hydrogen, and oxygen atoms, as in the preceding cases. But in addition, you also find *nitrogen*, and usually small amounts of some other elements such as sulfur and phosphorus. Actu-



2–12. Have you had one food from each of these groups today?

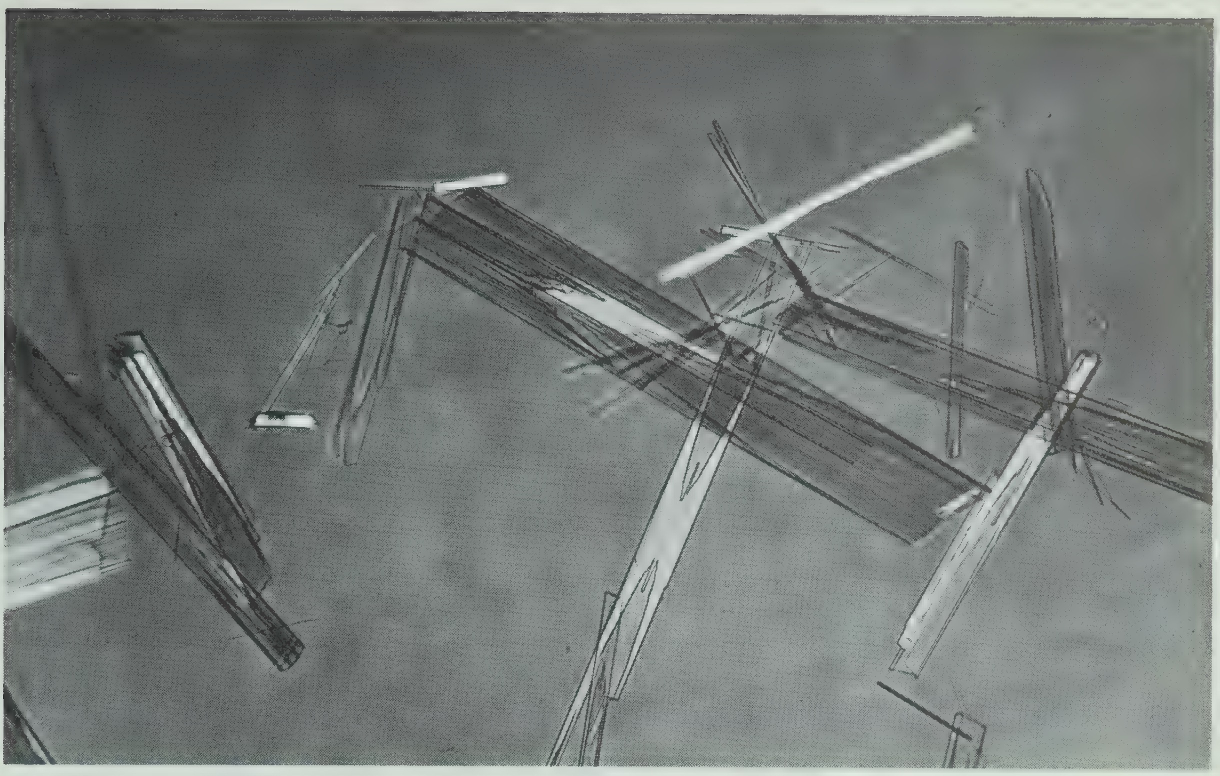
ally, the complex protein molecule represents the union of a number of simpler molecules. These simpler molecules are known as ***amino acids.*** When your body digests a protein molecule that you have eaten, the molecule is broken down into the amino acids of which it is composed.

The proteins are essential compounds of protoplasm. They are responsible for carrying out a variety of life processes. You have probably seen many samples of proteins. The white of an egg is largely protein, and so is lean meat or fish of any kind. Every cell of a plant or animal contains some proteins.

Enzymes (*en*-zymes) are a special group of proteins found in plant and animal cells. Enzymes make it possible for various chemical changes to take place. You might say that enzymes hasten certain changes. The enzymes are not used up in this process. Since life itself depends upon chemical changes, you can imagine how important enzymes really are.

Other compounds in protoplasm. Another group of compounds found in protoplasm includes the ***hormones*** (*hor*-moans). Some of these hormones are proteins, and others are not. They have been described as "chemical messengers," because they influence cell behavior. In complex animals they are produced by a number of special glands, and are discharged directly into the blood stream. The blood carries them to all parts of the body. When they reach certain cells, they bring about a variety of reactions.

In later studies you will learn a good deal about the ***nucleic*** (new-*klee*-ick) ***acids.*** These compounds are called *DNA* and *RNA.* To a large extent they determine what goes on in

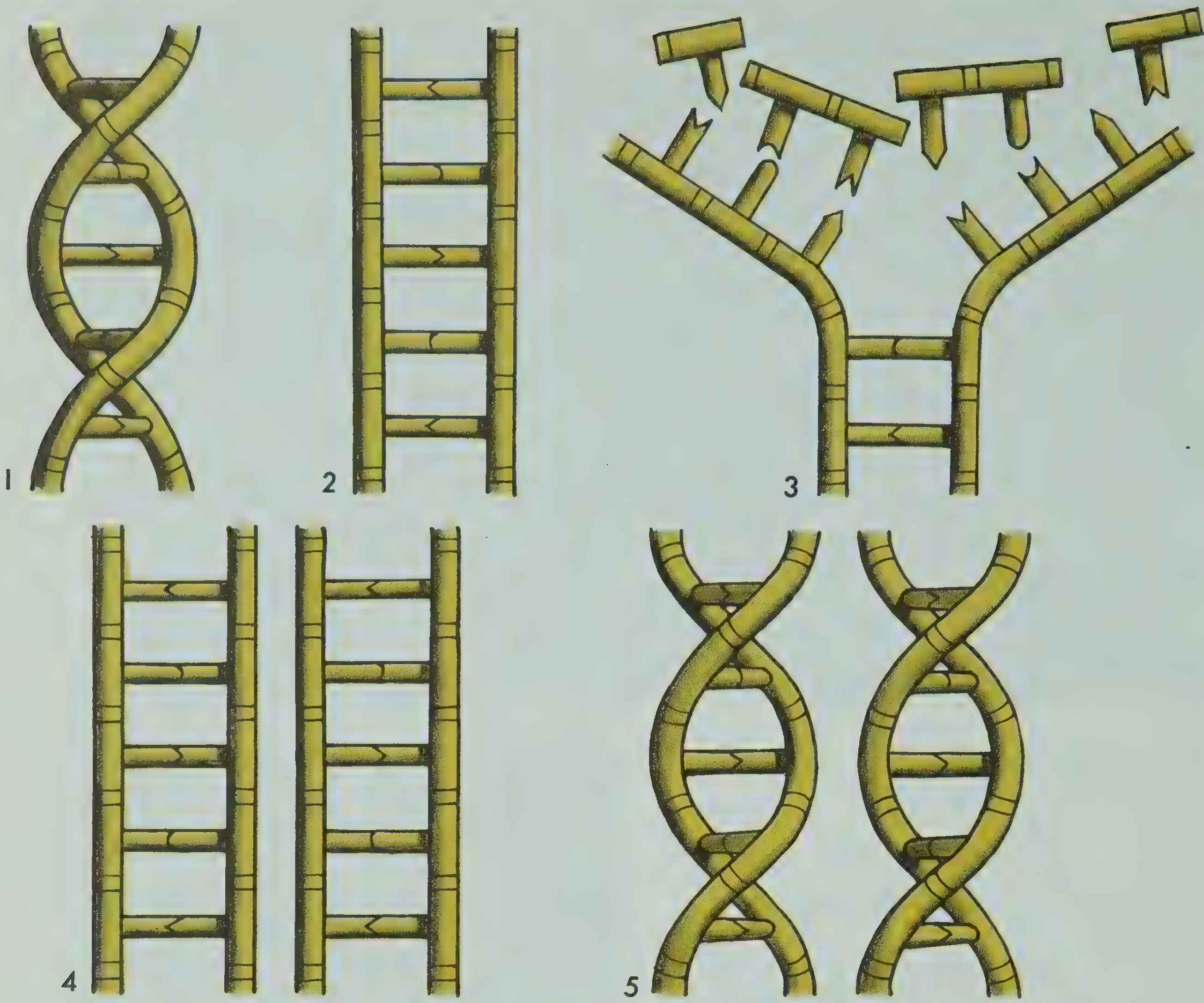


2–13. Photomicrograph of the hormone adrenalin. (*Schering Corporation*)

2–14. A model of the *DNA* molecule. (*BBC, Broadcasting House, London*)

the living cell. Both *DNA* and *RNA* can combine with protein molecules, and often do so. The large molecules so produced have an interesting ability. When the right chemical materials are available around them, they can duplicate themselves. This process is called *replication*. The parent molecule acts as a pattern for the development of another molecule of the same kind. We all know that plants and animals can reproduce their kind. But to find that some molecules can do much the same thing is a new and interesting concept.

Another group of compounds in protoplasm is made up of the *salts*, including common table salt. In plants and animals, various salts are found not only in cells, but also in the hard parts of skeletons and other supporting structures. Salts are made up of such ele-



2–15. *DNA* replication: (1) The double-stranded *DNA* molecule; (2) the two strands of the molecule unwind; (3) the strands begin to split, each strand developing new units to replicate itself; (4) two separate *DNA* molecules are formed; (5) the original twisted *DNA* structure appears.

ments as potassium, calcium, sodium, chlorine, sulfur, hydrogen, nitrogen, oxygen, and phosphorus.

TESTING FOR THE COMPOUNDS OF PROTOPLASM

When we look at an organism, we usually notice some of its qualities: color, size, shape, and texture. In so doing, we are making what is called a *qualitative observation.*

Similarly, we can study some of the qualities of protoplasm. We can, for example, test various substances that come from plants and animals to find out what sort of compounds they contain. Such tests are *qualitative tests* if they merely reveal the presence or absence of certain substances. After you have made a qualitative test, you may know that a certain substance is present, but you do not know *how much* of

	Starch	Simple sugar	Protein	Fat
Test A	No change	No change	Color changed to purple	No change

the substance is present. To determine how much is present, you must make a *quantitative test.*

TESTS FOR SUGARS, STARCHES, PROTEINS, AND FATS One of the following tests can be used to show that starch is present, another to show that the simple sugar, glucose, is present. One is a test for proteins, and one is a test for fats.

Test A. Place a small bit of the substance to be tested in a test tube, and add Biuret reagent.

Test B. Place a bit of the substance to be tested in a test tube. Add 10 cc of Fehling's solution A, and 10 cc of Fehling's solution B. Heat the contents of the tube to the boiling point.

Test C. Place the substance in a watch glass, and put several drops of iodine solution upon it.

Test D. Rub the substance against a small piece of unglazed paper. Let the paper dry.

Our problem here is to discover what *A, B, C,* and *D* are tests for. We can get our answers by trying them out on known substances. For instance, if we can test some starch (a carbohydrate), some simple sugar such as glucose (another carbohydrate), some gelatin (a protein), and some salad oil (a fat) with *Test A,* we shall begin to solve our problem. The record of our observations will look like the chart shown above.

Because of the color change, you can see that *Test A* can be used to detect the presence of a *protein.* Biuret reagent remains *blue* when it is added to starch, simple sugar, or a fat. But it changes to a *purple* color when it comes in contact with proteins.

Now prepare a data sheet in your notebook like the one shown below.

Try *Tests B, C,* and *D* on the four substances you used in *Test A.* Enter your observations on the data sheet. Which test reveals the presence of starch? Simple sugar? Fat? What changes take place when *Tests B, C,* and *D* are positive?

TESTING DIFFERENT MATERIALS Now that you know what these four tests reveal, you can use them to test various parts of plants and animals. You can test such things as pieces of potatoes, carrots, onions, and lettuce. Samples of animal materials such as pieces of a fish, an earthworm, a snail, or an insect can also be used. Prepare a data sheet in your notebook like the one at the top of page 34.

	Starch	Simple sugar	Protein	Fat
Test B				
Test C				
Test D				

Substance	Starch	Simple sugar	Protein	Fat
Potato				
Onion				
Fish				
Earthworm				

Now perform your tests and record the results. Note that you may find two or more of the substances you are testing for in a single sample. On your data sheet you can use a + mark to indicate a *positive* finding, and a − mark to indicate a *negative* result.

Which of the substances that you tested for seemed to be present in the largest number of samples? Which substance seemed to be least common?

ANALYSIS You have now learned to test for certain compounds that are found in protoplasm. In fact, you have tested such samples of protoplasm as a piece of potato, or a piece of fish. In your notebook, prepare answers to the following questions:

1. How do you explain the fact that a certain substance is found in most or all samples of protoplasm, and another substance in fewer samples?
2. In what ways, if any, did the plant samples you tested seem to differ from the animal samples?

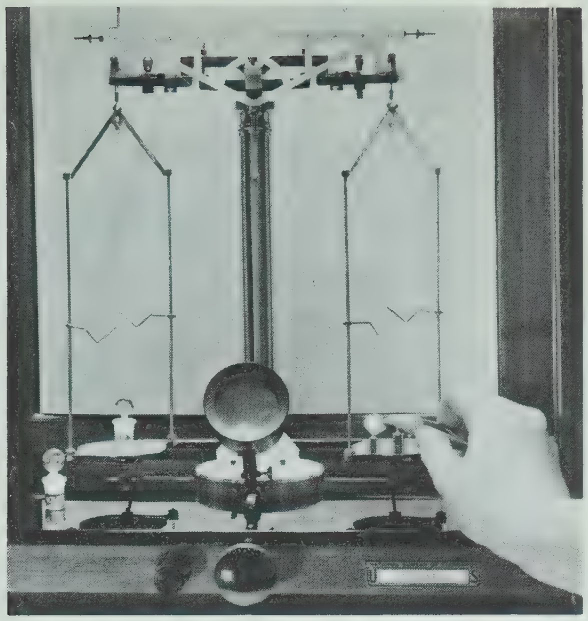
WATER IN PROTOPLASM In scientific studies it is often desirable to make careful measurements. A meter stick can be used to find the length or width of an object. A balance is used to determine weight. (See Fig. 2–16.) If a scientist wants to know how much of a certain chemical is present in some material, the job is likely to be more difficult. But there are ways of finding out, as you shall see.

When you make an exact measurement, it is a *quantitative observation.* Using a simple method, it is possible to find out *how much* water is present in a sample of protoplasm. The first step is to find out the weight of the sample. Then you must dry the sample to get rid of the water. Finally, you weigh the dried sample. The amount of weight loss is equal to the weight of the water that was in the fresh sample. So if a fresh sample weighs 100 grams, and after it has lost all of its water it weighs 50 grams, you know that the fresh sample was 50 percent water by weight.

Make a data sheet in your notebook like the one shown below.

Obtain some samples of plant and animal materials, as you did in the earlier tests. Weigh each sample carefully, and record the weight on your data sheet. Place the samples in an oven at low heat, and dry them thoroughly.

Kind of Protoplasm	Fresh Weight	Dry Weight	Weight Loss	Percentage of water
1.				
2.				
3.				



2–16. An analytical balance will aid you in making a quantitative test. (*National Bureau of Standards*)

Weigh the dried samples, and record the results on your data sheet. For each sample, find the amount of weight loss; then find the percentage of weight that was due to water in the fresh sample.

ANALYSIS Do not be surprised if you find variation in your samples. Some protoplasms contain a lot more water than others. Also, the drying process may not remove *all* of the water. In your notebook, prepare answers to the following questions:

1. What was the highest percentage of water in your samples? The lowest?
2. How do your results indicate that water is an important compound of protoplasm?
3. Why can you call this a *quantitative* investigation?

AN ENZYME OF PROTOPLASM On page 30 you learned that enzymes are special types of proteins that assist in bringing about chemical changes. The substance, hydrogen peroxide, which acts as a cell poison, is often formed in protoplasm. But the enzyme, ***catalase*** (*kata*-lase), is present, and as a result, hydrogen peroxide is broken down into two harmless substances: water and oxygen.

It is possible to tell whether any catalase is present in a sample of protoplasm. All you need to do is drop a tiny sample of the protoplasm into a beaker or test tube that contains some hydrogen peroxide. If catalase is present, the hydrogen peroxide begins to break down, and bubbles of oxygen gas rise to the surface.

Make a data sheet like this one in your notebook:

Kind of protoplasm	Catalase activity
1.	
2.	
3.	

Obtain several samples of plant and animal materials. Cut off pieces that are about the size of a pea. Put about an inch of 3 percent hydrogen peroxide in a test tube. Drop in a sample, and watch for a few moments to see if oxygen bubbles appear. Remove the sample as soon as you have finished your observation. One tube of hydrogen peroxide can be used to make several tests.

Record your observations as you make the tests. Use a + for a *few* oxygen bubbles, + + for a *medium* number, and + + + for a *great* number of bubbles. Use *N* (negative) for no bubbles.

ANALYSIS Prepare answers in your notebook to the following questions:

1. What kind of protoplasm appeared to contain the largest amount of catalase? The smallest?

2. How did the amounts of catalase in the plant samples compare with the amounts in the animal samples?
3. On the basis of these test results, would you be willing to conclude that all living materials contain catalase? In either case, what are your reasons?
4. Were these tests qualitative or quantitative? Explain.

AN INVESTIGATION YOU CAN PLAN Suppose you want to find out whether heat affects the activity of catalase. Suppose the samples used in the preceding tests had been 10 degrees warmer, or 10 degrees cooler? What would have happened if they had been boiled? Plan a series of tests designed to answer these questions. Be sure to include several kinds of plant and animal materials. After your teacher has approved your plan, carry out the investigation. Make a data sheet in your notebook, and record your observations.

ANALYSIS Prepare answers in your notebook to the following questions:

1. What effect did change of temperature have on catalase activity in plant protoplasm? In animal protoplasm?
2. Was your investigation qualitative or quantitative? If qualitative, how could you make it quantitative?

ENERGY FOR WORK

You have learned that protoplasm moves, even though this movement may be confined to a single cell, and that many chemical changes take place in this living substance. Energy is generally necessary to keep such activities going. Where does this energy come from? The answer will be found in the food we eat.

The process of oxidation. For example, the carbohydrate, glucose, can be broken down to provide the energy protoplasm must have. The breakdown begins when oxygen combines with the food material. This process is called ***oxidation*** (*oks*-suh-*da*-shun). Bonds between the atoms are broken, energy is set free, and in turn energy is trapped and held by a compound called *ADP*. When this happens, a special group of atoms is added to the *ADP* molecule, which then becomes a different molecule called *ATP*. This *ATP* molecule is an energy carrier. Sooner or later the energy of the *ATP* molecule is used by the cell to do work. Then it becomes an *ADP* molecule again, and is ready to trap more energy.

By using energy, protoplasm is able to carry on essential chemical changes, and form the various types of compounds that it contains. Some of these newly formed compounds are needed just to keep the protoplasm in repair. Others provide materials used in growth.

Some properties of protoplasm. Protoplasm can break down certain compounds and release energy. It can use the energy to move, and to produce materials that are required for growth and repair. All of the things we are talking about here are the products of chemical changes. As protoplasm carries on these changes, a number of waste products are formed. These waste products consist of substances that cannot be used, and may even be poisonous. Protoplasm gets rid of such wastes by the process of ***excretion*** (eks-*kree*-shun). Excretion will be discussed further in Chapter 13.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. atom	Includes all substances that exist in our environment.
2. matter	The smallest part of an element having all the properties of that element.
3. molecule	Compound that contains carbon, hydrogen, oxygen, and nitrogen.
4. oxidation	The smallest unit of a compound formed when atoms bond together.
5. protein	A process in which oxygen combines with a food material and energy is released.

B

1. amino acid	The general name given to a substance that speeds up certain chemical reactions.
2. *ATP*	May contain either *DNA* or *RNA*.
3. energy	A smaller molecule that results when a protein molecule is digested.
4. enzyme	A "chemical messenger."
5. *ADP*	The capacity to do work.
6. hormone	A molecule that stores energy released by oxidation.
7. nucleic acid	A molecule that is an energy carrier.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Protoplasm contains several elements that are found only in living material.
2. The four most common elements found in plants are the same as the four most common elements found in animals.
3. A substance with the formula $C_{12}H_{22}O_{11}$ would be a carbohydrate.
4. Both carbohydrates and fats can be broken down in the living cell to provide energy.

5. Enzymes are a special group of carbohydrate molecules.
6. *DNA* and *RNA* are examples of hormones.
7. To note the color of an object is a *qualitative* observation.
8. Atoms, like molecules, are composed of smaller parts.
9. Chloroplasts are found only in green plants.
10. A formula indicates only the kinds of atoms that are present in a molecule.
11. A molecule of water consists of three kinds of atoms.
12. The most common elements in protoplasm are carbon, hydrogen, oxygen, and water.
13. Sugars and starches are carbohydrate compounds.
14. Biuret reagent turns purple in the presence of starch.
15. In animal bodies, hormones are produced by cells of the blood.
16. There is more available energy in an *ATP* molecule than there is in an *ADP* molecule.
17. When oxygen combines with food materials we have oxidation.
18. Protoplasm gets rid of poisonous substances and other substances that cannot be used, by the process of excretion.

DISCUSSION QUESTIONS

1. In what ways do solids, liquids, and gases differ? In what ways are they alike?
2. In what ways are radioactive substances used in science and industry?
3. Atoms are much too small to be seen. Can you think of any evidence that will show that they really exist?
4. In what ways are the protoplasm of a hen's egg, a single-celled animal, an Irish potato, and an *Elodea* cell alike? Different?
5. Of what importance is water in the living substance?
6. If H_2O means two atoms of hydrogen and one atom of oxygen, what does $C_6H_{12}O_6$ mean?
7. Is there anything wrong with the statement, "A potato is carbohydrate and beef is protein"? Give the reason for your answer.
8. In what ways are fats and carbohydrates alike? Different?
9. Why are proteins important substances in protoplasm?
10. What is the relationship between amino acids and proteins?
11. What is the difference between a *qualitative* and a *quantitative* observation? Give examples of each.
12. Describe the activities that are carried on by protoplasm.
13. Are any of the activities that are carried on by protoplasm also carried on by nonliving things? Explain.
14. What characteristics of living things are most useful to you in distinguishing them from nonliving things?

THINGS TO DO

1. Make a collection of common elements. Label each with its chemical symbol. Describe how each element in your collection was obtained, and also describe some of its uses. Display your collection.
2. Assemble samples of about two dozen common compounds. Label each compound with its chemical formula. Describe how each sample was obtained, and ways in which the substance is used. Display your collection.
3. Prepare models of the molecules of various compounds. Marbles, beads, clay, and styrofoam are useful for representing atoms. Glue, toothpicks, and pipe cleaners can be used to hold the "atoms" together. Almost any chemistry book will help you decide how the "atoms" of your model should be arranged to represent a particular molecule. Include models of water and simple sugar.
4. Select a list of common foods. Describe what each food represented in the plant or animal from which it came. For example, spinach is a leaf of the spinach plant, a carrot is the root of a carrot plant, and steak represents muscle from a steer. Using pictures of foods, prepare a display of your findings.
5. Using pictures, prepare a bulletin board display to illustrate various kinds of energy, their sources, and their uses.
6. Prepare a bulletin board display to illustrate the various activities or functions of protoplasm.
7. Find out how the atoms of several common elements differ from one another. Report your findings to the class.
8. Find out what happens when an atom is split. Report your findings to the class.
9. If you have a Geiger counter available, collect small pieces of various kinds of rock, including pebbles from gravel, and test them for radioactivity. See if all samples give the same readings as the ground rate. If so, they are not radioactive.

READING FURTHER

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CHAPTER 3

Cells in Action

In most cases it is not difficult to tell plants and animals apart. It is rather obvious that a maple tree is a plant, and that a rabbit is an animal. But maple trees and rabbits are things you have seen before. Some of the smaller and less well known organisms would give you more trouble. Are they plants, or are they animals? Even scientists disagree about some types that they call "borderline."

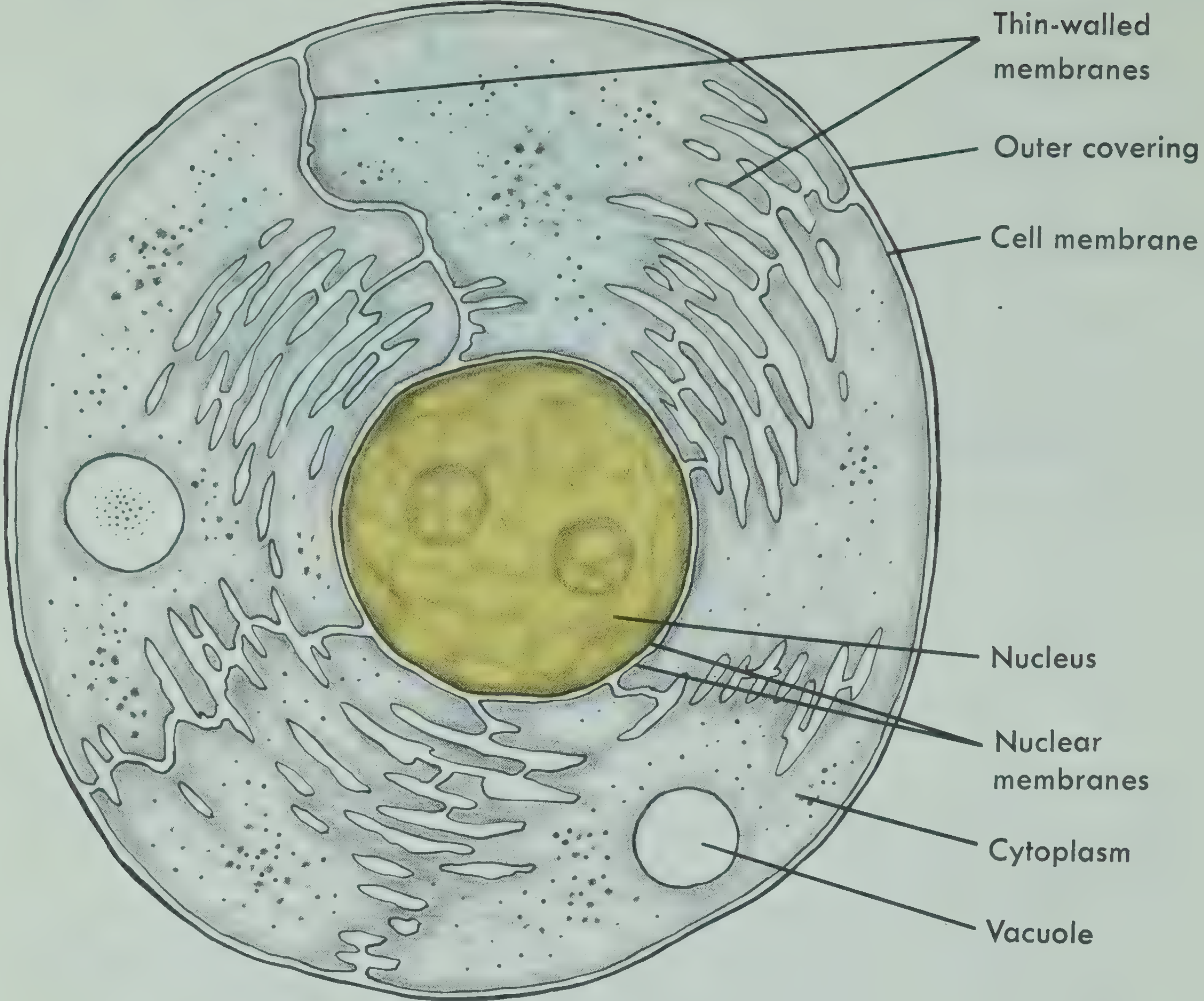
CELLS: THE UNITS OF STRUCTURE AND FUNCTION

Plants and animals are similar in some respects. You have learned that they are both made up of cells. Some plants and animals are single-celled, others have bodies made up of hundreds, thousands, millions, and even trillions of cells. Your own body is one that contains trillions of cells. We sometimes say that these cells are the units of *structure*. But we may also say that these cells are the units of *function*. For an organism's activities depend upon what happens in the cells of its body.

At this point you might ask, "Are all cells more or less alike?" This question cannot be answered by "Yes" or "No." They are alike in some respects and different in others. Cells differ in size. Most cells can only be seen by using a microscope. Others can be seen with the unaided eye. Cells also vary in shape. Some of them are more or less spherical, but others take different forms. Some cells can do a number of things fairly well, while other cells have rather specialized functions. So, cells differ a good deal in size, appearance, and ability to perform certain functions. But all cells are alike in one respect: they contain the living substance, protoplasm.

ANIMAL CELLS

Look at Fig. 3–1, which shows an animal cell. The outer, more fluid part

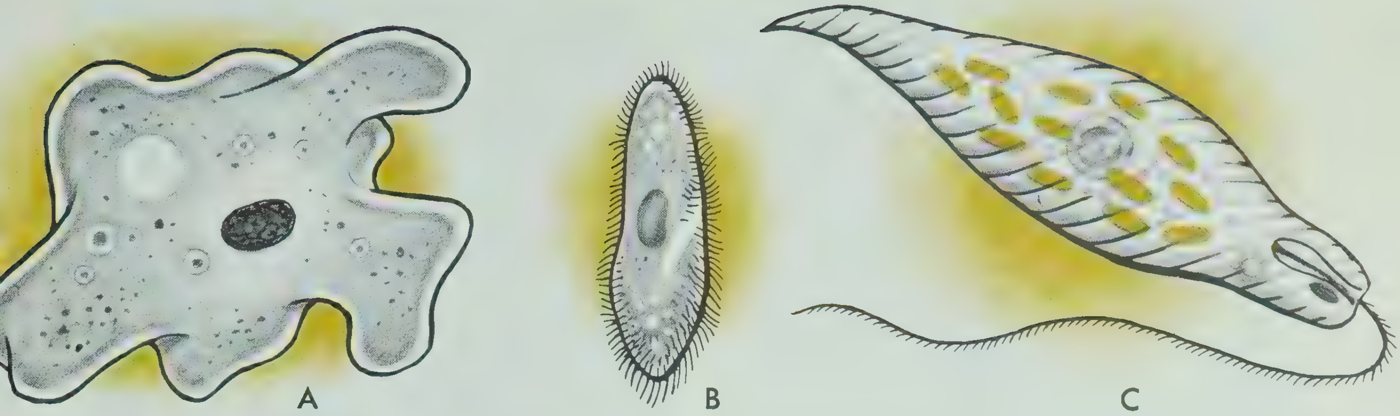


3–1. Diagram of a typical animal cell.

of the cell is the ***cytoplasm*** (*sy*-toh-plazm). A denser structure within the cell is the ***nucleus*** (*new*-klee-us). On the outside of the cell is a porous covering, which differs in various animal cells, and is absent in some of them. Just inside this covering is a very thin inner covering called the ***cell membrane.*** It is the *outer boundary* of the living material. The cytoplasm includes all the living material in the cell except the nucleus.

Around the nucleus there are two membranes, which lie very close together. They are the ***nuclear membranes.*** Thin-walled membranes also extend from the cell membrane to the nuclear membranes, dividing the cytoplasm into a number of compartments. All of the membranes are porous to the extent that certain molecules can pass through them. All of the membranes are also flexible.

A good many small, solid particles appear in the cytoplasm. At this point in our study we shall simply call them ***granules.*** These granules vary in size and shape. Some of them are centers where important life processes take place. One or two ***vacuoles*** (*vack*-yoo-oles) may also appear in the cytoplasm, as shown in Fig. 3–1. Some of the vacuoles form around food particles that are being digested. Other vacuoles are filled with liquid wastes, or serve to store food reserves.



3–2. Three types of locomotion are found among single-celled organisms. (A) One or two processes of the cytoplasm are extended, and the rest of the cell moves into them. (B) Cilia move back and forth and propel the cell. (C) the flagellum lashes the water, causing the cell to move.

There are various special structures in the nucleus that you will learn about later on. In fact, it is thought that the nucleus is a sort of *control center* that *regulates* cell activities. It is very important in the life of the cell. You should also remember that both the cytoplasm and the nucleus are made up of the living substance—protoplasm.

Motion and locomotion. As you learned in Chapter 2, materials in the living substance move about. Protoplasm is never at rest; molecules move about in it all of the time. But in addition, some cells are able to move from one place to another, and this act is known as *locomotion.*

In Fig. 3–2, the organism in *A* moves by extending fingerlike processes, and then flowing into them. This might be called a slow but sure method. The cells shown in *B* and *C* can move about much faster. In *B*, tiny extensions of the cytoplasm, known as ***cilia*** (*sih*-lee-uh), extend out through little openings in the cell surface. When all or most of the cilia beat against the water, the cell is moved along. In *C*, the process that lashes the water is called a ***flagellum*** (fla-*gell*-um). A flagellum is a good deal longer than a cilium, but operate in much the same manner.

Do not fail to note that both cilia and flagella are extensions of the cytoplasm. As such, they are living parts of the cell. Some single-celled organisms that live in freshwater ponds and streams have a particularly long flagel-

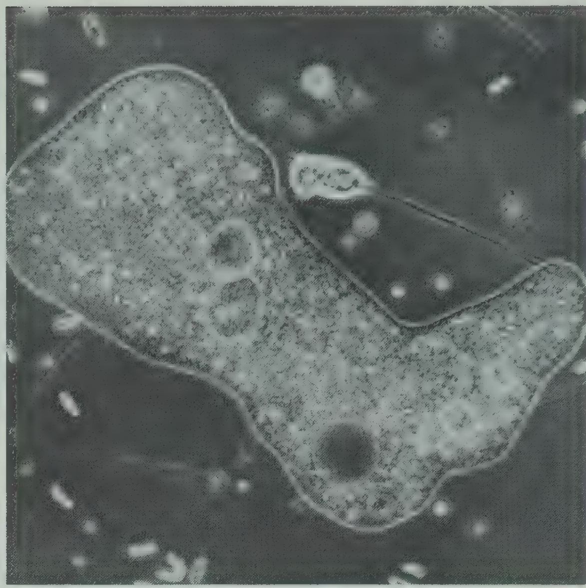
3–3. A *euglena.* Can you identify the flagellum? (*Walter Dawn*)

lum. In Fig. 3–3 you see a greatly enlarged photograph of one of them.

Can all animal cells move about under their own power? By no means. Some cells of your own body, such as the white blood cells, do move from place to place, but a lot of others, like muscle or bone cells are fixed in position. Some single-celled animals can propel themselves about in the water, but others have no means of doing so, although they may be carried along by water currents.

Responses to stimuli. Maybe you are wondering what would stimulate a single-celled aquatic organism to move about. If so, look up the experiment with *Paramecium* (*pahr*-uh-*mee*-see-um) described on page 121 of this book. In this experiment, the paramecium moves and avoids contact with a red stain. The stain acts as a *stimulus,* and the movement away from the stain is a *response.* In the ordinary course of events, cells receive many stimuli. They are attracted by some of them and repelled by others. The same paramecium that is repelled by the red stain may be attracted by food materials in the water. So a cell can receive stimuli and it can make responses. To put it another way, the living substance is *sensitive.*

Food and digestion. Animal cells take in food particles in various ways. All of them must have food to supply energy, and to build and repair their substance. Often, molecules of food merely pass through the outer covering of the cell. But some animal cells have special structures for taking in food particles. In all cases, however, the food particles enter the cytoplasm, where they are digested. Digestion means that the food particles are broken down by chemical action until they



3–4. An ameba about to engulf another one-celled organism (*Vorticella*). (*Walter Dawn*)

are soluble in water and can be absorbed by the cells. Digestive enzymes aid in this process. In this way, molecules derived from food can become a part of the living substance. These molecules provide energy, and materials for growth and repair.

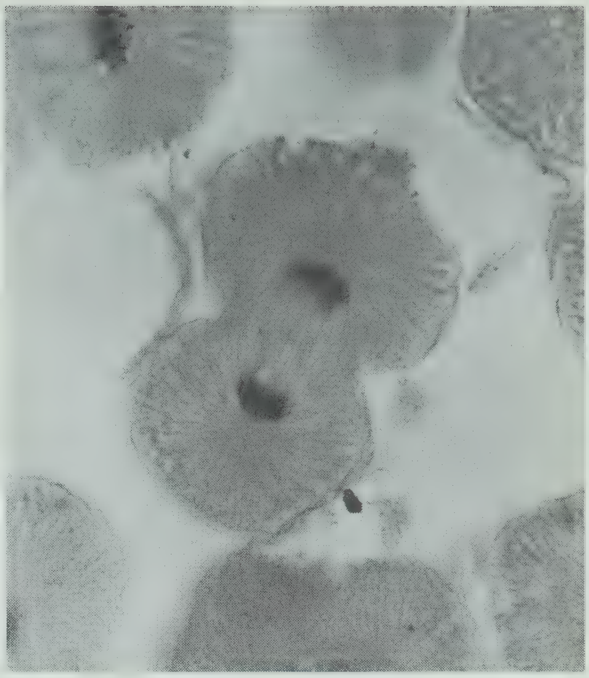
The use of oxygen. Most living cells must have a supply of oxygen. Oxygen is one of the gases in air. It is also dissolved in the waters of ponds, streams, and seas. An ameba simply takes in oxygen through its cell membrane. The oxygen is used in the breakdown of food molecules. Energy in the food molecules is released to do work. In this process carbon dioxide is formed as a waste product.

Waste removal. As a cell carries on its life processes, various wastes are formed. Carbon dioxide is a waste product of both plant and animal cells, although you will find that some plants use the same carbon dioxide in food making. Cells must get rid of their waste products. A single-celled organism that lives in a pond simply dis-

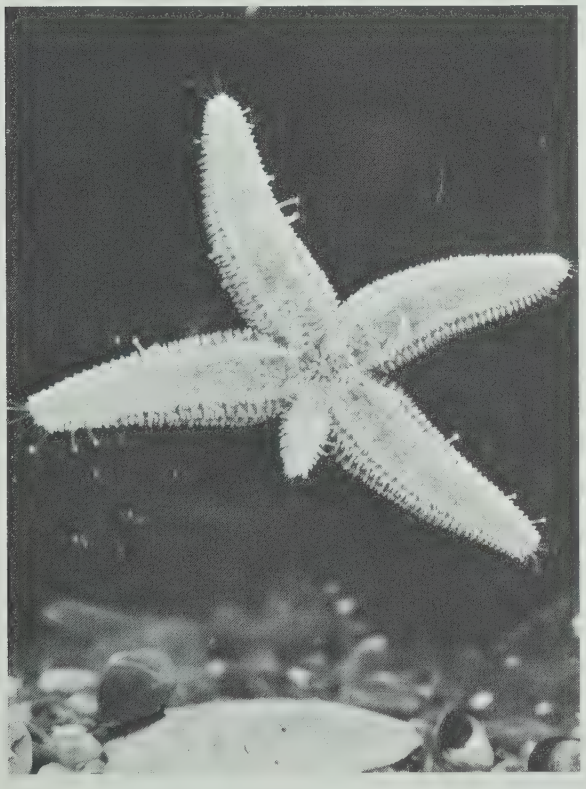
charges carbon dioxide into the water. A cell within the body of a large animal also discharges this waste. But in a large animal, this process is much more complex. In a large animal the carbon dioxide enters the blood, and passes out of the body through either the gills or lungs.

Organisms also produce certain liquid and solid wastes. A single-celled organism discharges such wastes into the surrounding water. In large organisms, the removal of liquid wastes often depends upon the blood stream. In many cases the blood carries these wastes to the kidneys, and they pass out of the body as part of the urine. In a large animal, solid wastes, which are the by-products of digestion, pass out of the body through a digestive canal.

Growth and repair. A living cell is in a constant state of change. Some of its substance is always being broken down to provide needed energy and materials. New substance is being built up to replace what has been lost. Growth continues to a certain point, and replacement or repair is necessary as long as the cell lives.



3–6. One of the steps in cell division as seen under the electron microscope. (*The Upjohn Company*)



3–5. Replacement or regeneration of an arm in a starfish. (*Charles Wolcott*)

In your own body many cells become worn out and die. For instance, you are losing old, worn out cells from the surface of your skin all of the time. The average life-span of a red blood cell is about three months. If you cut a finger, you destroy a number of cells. The loss of these cells, however, is soon made good. Surrounding cells divide, the new cells grow, and the cut heals.

Cell division. When a cell has grown to full size, it often divides to form two new cells. In a single-celled plant or animal, the two new cells separate, and each goes its own way. These two new cells are like the parent cell, except that they are smaller in size. They take in food materials, and soon grow to full size. Here, cell division re-

3–7. Diagram illustrating the general course of cell division in both plant and animal cells.

sults in ***reproduction*** (ree-pro-*duck*-shun), because two new individuals have been produced.

A general outline of what happens in cell division is shown in Fig. 3–7. In *A*, we have the parent cell, which has not yet begun to divide. In *B*, the nucleus of the parent cell shows signs of dividing. In *C*, division of the nucleus is about completed, and the cytoplasm is beginning to divide. In *D*, two new cells have been produced.

Of course, this is only an outline of what happens when a cell divides. You will learn other details as you continue your study of biology. You will find, for example, that various cells divide in somewhat different ways. There is one single-celled organism called *Chaos* that generally produces three new cells when it divides. In this case, both the nucleus and the cytoplasm give rise to three equal parts.

Remember also that cell division often results in *growth* rather than reproduction. When a cell in the root of a plant divides, the result is usually growth. Naturally, the division of one cell will not produce much growth. But if a good many cells divide, and the new cells grow, the growth becomes evident. You can see that the root has become larger. The new cells that are produced add to the size of the root.

PARAMECIUM: A SINGLE-CELLED ORGANISM

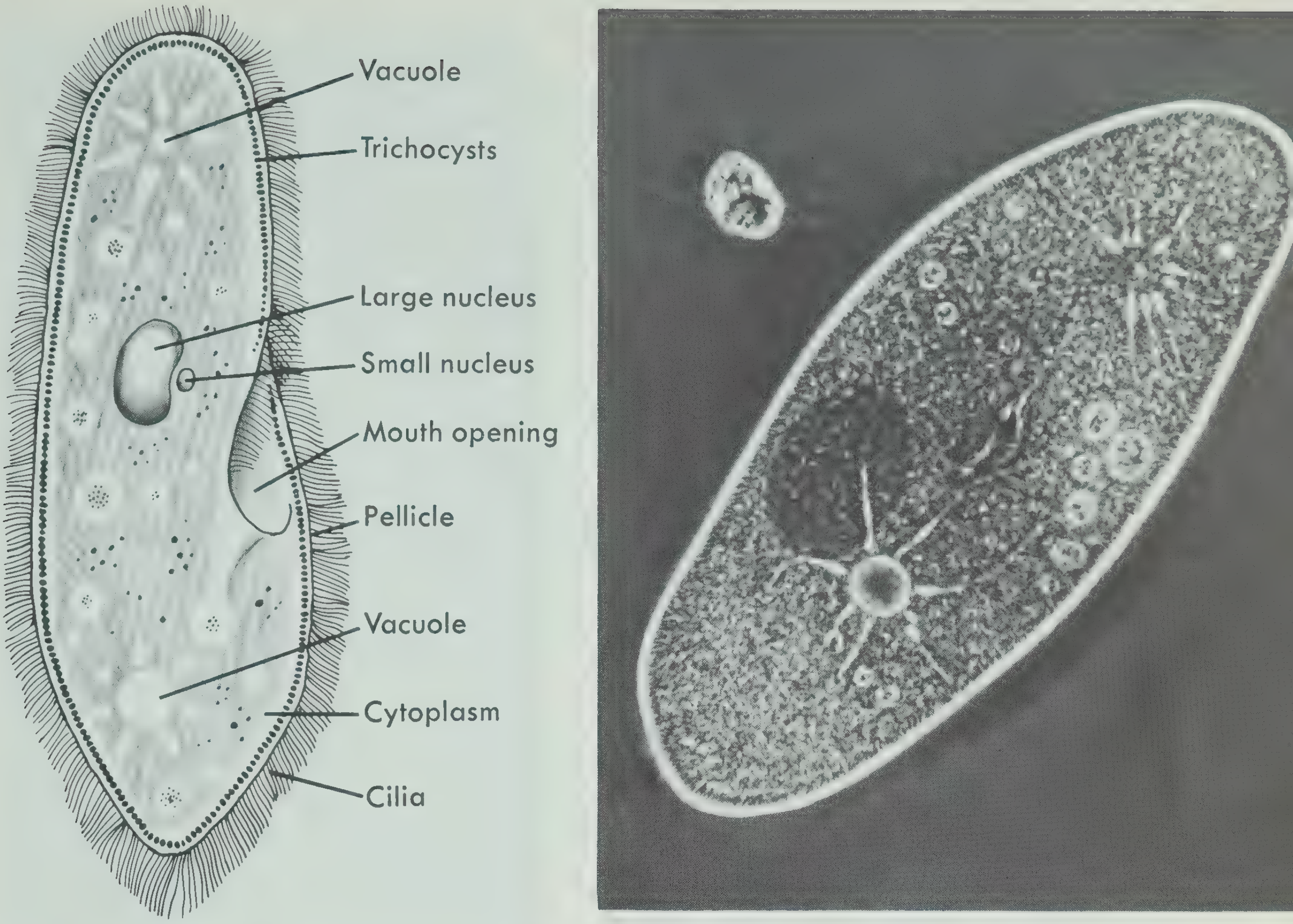
The paramecium is one of the common single-celled organisms found in ponds. If you have sharp eyes you can see a paramecium as a tiny speck in the water.

Shape and general structure. A paramecium has a more or less definite shape, as shown in Fig. 3–8. Most of the cell is filled with cytoplasm, in which vacuoles appear. There is a large nucleus. In addition, some kinds of paramecia have one small nucleus and others have two or more small nuclei.

A paramecium has a thin cell membrane around its cytoplasm. Outside the cell membrane is a much thicker ***pellicle*** (*pell*-ik-ul). The pellicle has a lot of tiny openings in its surface, and cilia extend out through these openings. Cilia are threadlike extensions of the cytoplasm. The cilia move back and forth to propel the organism through the water.

Food and digestion. A mouth opening is located on one side of a paramecium's body. Cilia around this mouth opening wash food substances such as bacteria into the cytoplasm. Small groups of bacteria make up a good deal of a paramecium's food. In the cytoplasm, a small ***food vacuole*** forms around a food substance. Enzymes from the cytoplasm enter this food vacuole, and act to digest or break down the food substance into simple compounds that are soluble in water. Now these soluble materials become a part of the surrounding cytoplasm. They are a source of energy, and they provide materials for growth and repair.

Oxygen supplies. A paramecium has no special structures for obtaining oxygen from the surrounding water.



3–8. Can you identify all the structures in the live paramecium on the right? (*Walter Dawn*)

Yet it must have oxygen if it is to obtain energy and live. The oxygen simply comes in through the pellicle and cell membrane.

Excretion of wastes. When food materials are digested, some solid wastes remain. Masses of these wastes leave the cell through a small pore below the mouth opening. Some wastes in the form of liquids and gases may simply pass out through the cell membrane and the pellicle.

In addition, there is excess water, for water is being steadily washed in through the mouth opening. At each end of the cell is a large vacuole, and these two vacuoles are busy all the time. One of them fills up with excess water, and perhaps some liquid waste. Then the cytoplasm around it contracts, and water is forced out through the cell surface. Meanwhile, the vacuole at the other end of the cell has begun to fill, and soon it will repeat the process of discharging liquid. Several canals extend from each vacuole while it is filling and give the vacuole a star-like appearance. Water drains through these canals into the vacuoles.

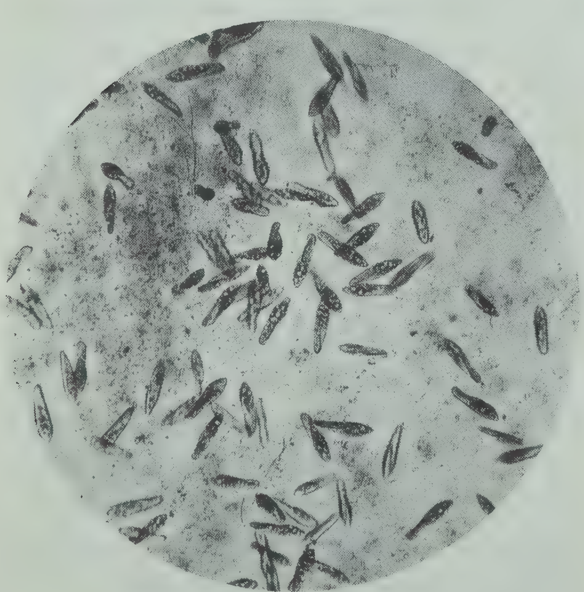
Growth and cell division. When a paramecium is in a favorable environment it feeds and grows. Sooner or later it becomes full-sized. Then the cell divides through its *short* axis, and the result is two new paramecia. Each paramecium is exactly like the other.

AN OBSERVATION OF PARAMECIUM

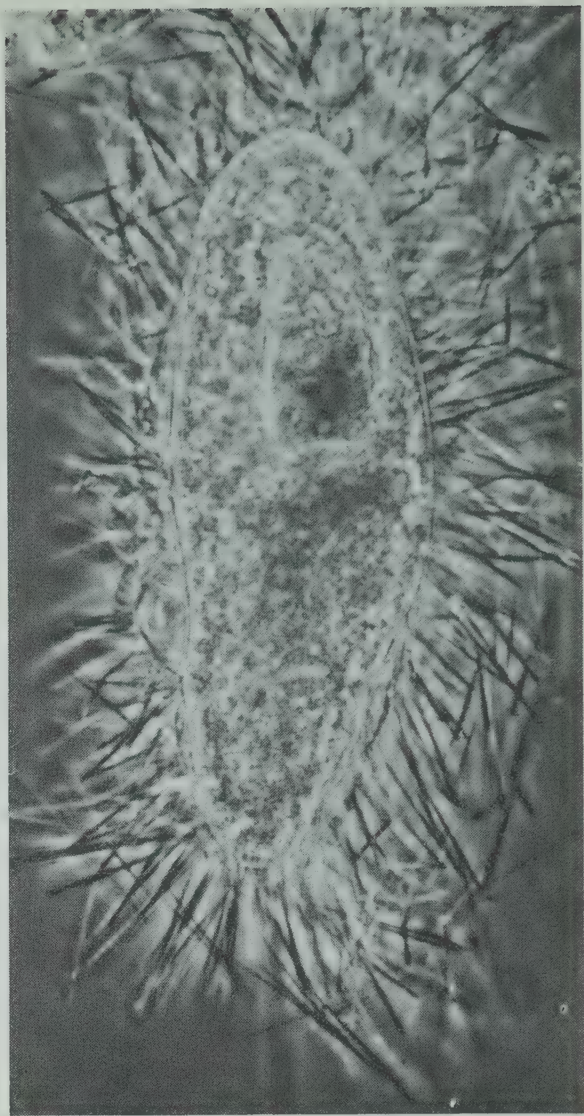
If you have a pond culture at hand, it is likely to contain some paramecia. You can also obtain cultures from biological supply houses.

OBSERVING PARAMECIA IN A DROP OF CULTURE Place a drop of culture on a blank slide, and cover it with a cover glass. Following the instructions on pages 112 and 113 of this book, focus on the culture drop with a microscope. If paramecia are present you will soon see them moving about.

In locomotion you will see that the same end of the cell usually goes *forward*. See what happens when the little organism collides with a solid object in the water. Try to locate the structures shown in Fig. 3–8.



3–9. A paramecium culture. (*Courtesy, General Biological Supply House, Inc., Chicago*)



3–10. Paramecium "exploding" its trichocysts after being treated by iodine which has a very irritating effect on the organism. (*Eric Gravé from Photo Researchers*)

PARAMECIUM'S DEFENSE MECHANISM Paramecia have a special type of defense mechanism that you may be able to see. To try this, put about three drops of paramecium culture on a blank slide, and focus upon a specimen with the high power of a microscope. Now add a tiny drop of iodine solution to the culture material, while carefully watching your specimen.

Do you see a lot of threadlike processes being shot out beyond the cilia?

They are filaments of the living substance which come out through little pores in the pellicle. Just within the pellicle is a layer of ***trichocysts*** (*trick*-oh-cists). When the organism encounters certain things in the water, the trichocysts discharge their filaments. Actually, this is no defense against iodine solution, but it might serve to ward off a tiny enemy.

ANALYSIS Now that you have made some observations of a living cell, prepare answers to these questions in your notebook:

1. When you look at a paramecium through the microscope, is it really moving as fast as it seems to move? Give reasons for your answer.
2. What is the shape of a paramecium? You are able to see how long and how wide it is, but do you know how thick it is? How could you measure its thickness?
3. What is the source of the water discharged by the two large vacuoles of a paramecium?
4. Why is oxygen necessary to the existence of a paramecium?
5. What evidence do you have that a paramecium is sensitive to external factors?

PLANT CELLS

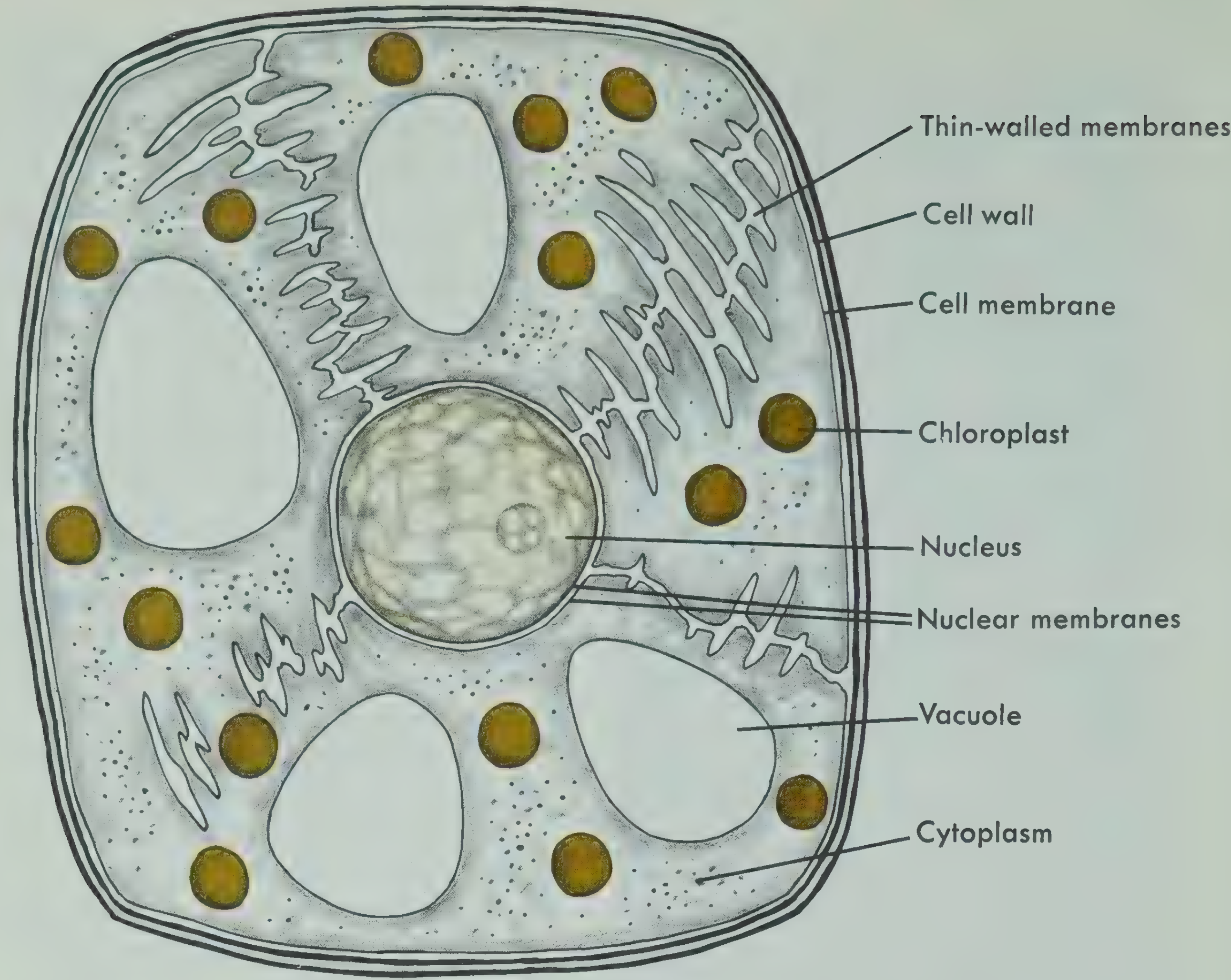
So far, we have given most of our attention to animal cells. Now let us look at a diagram of a single-celled plant, as shown in Fig. 3–11. This plant cell has a nucleus and a cytoplasm, just like an animal cell. It may live in the waters of ponds, lakes, or streams, as many single-celled animals do. Like the animal cells you have studied, it is sensitive, it uses the energy supplied by foods, it discharges wastes, it grows, and may divide to form two cells.

This plant cell has no means of locomotion, although some other green plant cells do. Note also that its outer covering is called the ***cell wall,*** which is not the same as the coverings of animal cells. The main thing that is different about this plant cell, however, is that it contains the green substance, known as ***chlorophyll*** (*klor*-roh-fill). It is the chlorophyll that gives many plants their green color. In the cell shown in Fig. 3–12, the chlorophyll is usually located in a single structure called a *chloroplast,* which floats about in the cytoplasm. In the *Elodea* leaf that you studied on page 26, the chlorophyll was located in many small chloroplasts.

Food manufacture by green plants. When a cell contains chlorophyll, it is able to make foods out of nonliving materials. Animal cells do not contain chlorophyll, and they are unable to produce their own foods. Animals must obtain their foods by eating plants, or other animals, or both.

The green plant cell is a food maker. It uses two common substances in the food-making process. One of them is *water,* which various plants get from oceans, ponds, lakes, streams, and damp soil. Another is the same *carbon dioxide* gas that is formed as a waste product when cells carry on their life processes.

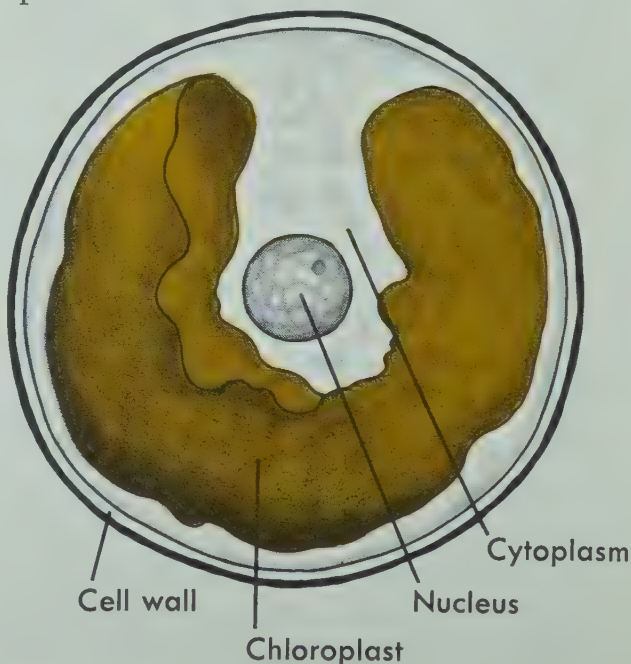
If a green plant cell has supplies of carbon dioxide and water, it is able to carry on a series of chemical changes that end in the production of foods. Of course, chlorophyll is also necessary. The energy needed to start this process comes from *sunlight.* One of the important foods manufactured in this way is the simple sugar known as *glucose.*



3–11. A typical green plant cell. What similarities can you find between the typical animal cell and the typical plant cell?

The process of food manufacture in green plant cells is called ***photosynthesis*** (*foh*-toh-*sin*-theh-sus), which means manufacture by light. There are two phases in this food-making process: a *light phase* which requires light energy, and a *dark phase* which can proceed without light. In the light phase, chlorophyll receives energy from sunlight, and changes this energy into chemical energy. The chemical energy is then used to break down water into hydrogen and oxygen. The oxygen gas is set free, but the hydrogen is retained for use in the dark phase. In the dark phase, carbon dioxide and hydrogen are used in a series of changes that result in production of

3–12. *Protococcus,* a one-celled green plant.



3–13. A chloroplast of a bean plant. (*T. Elliot Weier, University of California, Davis*)

simple sugar. Here is a summary of these two phases of the food-making process:

Light Phase

1. Chlorophyll changes sunlight energy into chemical energy.
2. Chemical energy is used to split water into hydrogen and oxygen.
3. The oxygen is set free, but the hydrogen is retained and is used in the dark phase.

Dark Phase

1. Carbon dioxide and hydrogen are combined in a series of chemical changes.
2. After several intermediate compounds have been formed, simple sugar is produced.

Simple sugar is a basic food. Green plants also make other foods such as starch, plant oils, and proteins. They use these foods to supply the materials and energy needed for growth, repair, and reproduction. Meanwhile, green plants provide foods for animals. If there were no plants to make foods, animals would soon cease to exist.

A SINGLE-CELLED PLANT

Now that you have a general picture of the green plant cell and its activities, you may wish to look at an actual example of plant life. If you live where there is frequent rainfall, you probably have seen bright green films growing on the moist surfaces of trees, rocks, and soil. These films are composed of single-celled plants that belong to a group known as the *algae* (*al-*

3–14. Pond algae. (*Grant Heilman*)

jee). You can find other single-celled algae in pond cultures that you either collect or obtain from a biological supply house. A picture of pond algae is shown in Fig. 3–14.

Place some of the cells on a blank slide, add a drop of water, and cover with a cover glass. Focus upon the specimens with the low power and then the high power of a microscope.

THE CELL WALL AND CELL MEMBRANE Notice first the outer covering of the cell. What you see is the ***cell wall.*** It is a *lifeless* covering around the cell that has been secreted by the cytoplasm. The cell membrane lies just inside it, but is too thin to be seen. However, the cell membrane is very important. As in other cells, it is the structure which permits some molecules to leave the cell, and other molecules to enter the cell. If all molecules could move in and out freely, the cell would soon lose its ability to carry on life processes.

THE CELL CONTENTS The first thing you are likely to notice in the cytoplasm of this cell are the numerous small, greenish chloroplasts. These are the food-making centers. See if you can locate a rather small nucleus, which looks more solid than the surrounding cytoplasm. The cytoplasm will appear somewhat granular.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How would a cell like this, living on the land, obtain its water supplies?
2. If you kept these cells in the dark, would they survive? What reason can you give for your answer?
3. When these cells are making food at a rapid rate, what gas do they discharge?

NONGREEN PLANTS

You may have noticed that we have been reading about green plants. It would now be reasonable for you to ask, "Are all plants green plants?" The answer is an emphatic "No." There are many nongreen plants, especially among the smaller and simpler types.

Some plants are dependent. The fungi you read about in Chapter 1 cannot make food. Neither can most of the tiny, single-celled organisms called ***bacteria*** (bak-*tih*-ree-uh). But among the bacteria there are some interesting exceptions.

Some special food-making processes. A few of the bacteria do contain chlorophyll, and they make basic foods, though not in the same way that other plants do. Instead of using water and carbon dioxide as raw materials, these

bacteria use hydrogen sulfide and carbon dioxide. Notice, however, that the energy used to begin the food-making process comes from sunlight, just as in the case of the green plants.

Some of the bacteria that have *no* chlorophyll are able to make food despite this handicap. They employ a process known as ***chemosynthesis*** (*kem*-oh-*sin*-theh-sus), or manufacture by chemical means. In chemosynthesis, the bacteria use energy of their own to combine substances like iron or sulfur with oxygen. More energy is *released* in this process than is *used,* and this energy is then used to change water and carbon dioxide into simple sugar and oxygen. This method of food making differs from photosynthesis because it does *not* require the energy of sunlight to get it started. In fact, these bacteria live buried in the mud of swamps.

AN ACTIVITY OF CELL MEMBRANES

Now, you may wish to investigate the way in which a cell membrane functions. When a cell is alive, its cell membrane allows certain substances to enter and leave the cell. At the same time, the cell membrane prevents other substances from entering or leaving the cell. Thus, a cell membrane may be called *semipermeable,* because it allows only certain substances to pass through. ***Osmosis*** (oz-*moh*-sus) is the passage of water molecules through a semipermeable membrane. An interesting group of experiments concerned with osmosis will be found on pages 119 and 120.

TESTING CELLS OF A BEET ROOT Beet plants are green plants, as you can see when you examine their leaves. Their underground parts are swollen roots that we harvest and use as food. When you cut into a beet, you find that its cells contain a red pigment which gives the beet its color. Normally, this red substance is held within the beet cells by the *cell membranes.* But if the cell membranes are *damaged,* the red substance can leak out. We can use this information to test the effect of heat on beet cells.

Cut off two thin slices from a raw beet. Rinse the slices in water. Place each slice in a separate beaker and cover it with about an inch of water. Now heat one beaker with its beet slice until the water has boiled for a few minutes. Use a water bath as described on pages 122 and 123 of this book. Observe what happens.

ANALYSIS In your notebook, prepare answers to the following questions:

1. What difference did you notice between the water in the two beakers after one of them was heated?
2. How can this difference be explained in terms of cell membrane activity?
3. What factors other than heat do you think might affect cell membrane activity?
4. How could you test one of these factors?

A TEST USING YEAST CELLS Yeasts are small, *nongreen* plants. They are among the many different types of *fungi.* It is known that the membranes of living yeast cells will not allow the stain called *congo red* to enter the cells. But if something happens to a yeast cell to damage the cell membrane, congo

red can enter, and the protoplasm becomes stained. Using this information, you can test the functioning of yeast cell membranes.

Prepare a yeast cell suspension by stirring some crumbled yeast cake or active dry yeast powder into a beaker of water. Add drops of congo red stain to the suspension until it is a bright red color. Pour half of the suspension into another beaker, and heat this second beaker in a water bath (see pages 122 and 123) until the suspension comes to a boil. Now prepare microscope slides of both the unheated and the heated suspensions. Observe the cells on the two slides, using both low and high powers of your microscope.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What difference did you find in the color of the heated and unheated yeast cells? How can this difference be explained?
2. Did any of the unheated yeast cells become stained? If so, how do you explain what happened?

A TEST YOU CAN PLAN Suppose you now want to answer the question, "Does freezing affect yeast cell-membrane activities?" Plan an investigation that will give you some answers. You may want to keep some yeast suspension overnight in the freezing compartment of a refrigerator. Be sure to include a control in your plan. You can do this by keeping some of the same yeast suspension at room temperature. If your teacher approves of the plan, carry out the investigation.

ANALYSIS If you planned and carried out a test on the effects of freezing, prepare answers to the following questions in your notebook:

1. What effect did freezing have on yeast cell-membrane activity? What evidence supports your answer?
2. What was the control in your experiment? Why was it necessary?

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. cell membrane	Outer and more fluid part of a cell.
2. chlorophyll	Thin covering around a cell's cytoplasm.
3. cytoplasm	Breakdown of food substances into simpler compounds.
4. digestion	Covering surrounding the cell of a paramecium.

5. pellicle	Green substance in certain plant cells.
6. photosynthesis	Process of using light energy to make foods.

● *B*

1. carbon dioxide	Passage of water molecules through a semipermeable membrane.
2. chemosynthesis	Control center of a cell.
3. nucleus	Cell structure filled with wastes or food particles.
4. reproduction	A waste product of life processes.
5. vacuole	Production of new individuals.
6. osmosis	Process of food making without light energy.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The best rule for telling plants from animals is "Living things that move are animals and those that do not move are plants."
2. Both plants and animals are made up of cells.
3. Living things almost never contain more than a few thousand cells.
4. Although cells provide the building blocks of life, the important life functions take place outside of cells.
5. Most cells are quite similar in size and shape.
6. The nuclear membrane is a double membrane.
7. Cell membranes are generally porous enough so that molecules of certain substances can pass through them.
8. The cytoplasm and the nucleus make up the protoplasm of a cell.
9. The faster moving one-celled animals usually move by means of fingerlike processes.
10. The euglena moves with the aid of a flagellum.
11. What an organism does after receiving a stimulus is called the response.
12. Chemical substances such as simple sugars that are soluble in water would undergo little or no digestion.
13. Although carbon dioxide is a waste product of life processes in plants and animals, it can be used by certain organisms in the process of food making.
14. In certain organisms cell division results in reproduction.
15. When some cells undergo division, three new cells result.
16. A paramecium takes in food through any part of its cell membrane.

17. The contractile vacuoles of a paramecium function to bring water into the cell.
18. The chloroplasts in animal cells are generally larger than the chloroplasts in plant cells.
19. Glucose is formed during the dark phase of photosynthesis.
20. The cell wall is considered to be a living part of the cell.
21. Some bacteria can manufacture food using hydrogen sulfide and carbon dioxide as raw materials.
22. Cell membranes are called semipermeable because they allow all substances to pass through.

DISCUSSION QUESTIONS

1. If you discovered a new kind of organism, how would you decide whether to call it a plant or an animal? Could it be placed in another category?
2. What is meant by the statement, "Cells are units of structure and function"?
3. In what ways are cells specialized to do certain things?
4. How would you distinguish between motion and locomotion?
5. Why do living things need food?
6. Why do living things need to digest food?
7. How do living things get rid of waste materials?
8. In what ways are growth and repair related?
9. How do cells divide?
10. In what ways are plant and animal cells alike? How are they different?
11. What is meant by the statement, "Animals depend upon green plants"?
12. What are the functions of cell membranes?
13. How do nongreen plants obtain food?
14. How can you account for the fact that plant tissue is generally harder and less flexible than animal tissue?

THINGS TO DO

1. Prepare a model of a plant or animal cell. You may want to use a jar to represent a cell wall, a plastic bag to represent a cell membrane, a ball to represent a nucleus, etc. Label each part of your model and display it for the class.

2. Prepare a bulletin board display to illustrate the differences between typical green plant and animal cells. You may want to represent cell parts by cutting outlines from various colors of construction paper. Label each part and indicate its function.
3. Prepare models to illustrate the various ways in which cells move—fingerlike extensions, cilia, and flagella. You may want to carve appropriate shapes from styrofoam. A piece of yarn or pipe cleaner can be used to represent the cell extensions used in locomotion.
4. Prepare a display to illustrate the relative size of various kinds of cells. Assume that the outline of a cell is a circle. The following data may be helpful in deciding how large to make certain forms.

Kind of cell	*Relative size*
Bacteria	1
Small white blood cell	8
Red blood cell	14
Large white blood cell	30
Liver cell	40
Cheek cell	100
Sea urchin egg cell	140
Ameba	200
Hummingbird egg	20,000

The numbers indicate that a bacterial cell is being used as the standard. Its diameter is given as 1 unit. The diameter of the small white blood cell is eight times as great or 8 units. The diameter of a red blood cell is fourteen times as great as that of a bacterial cell.
5. Are humans dependent upon green plants for their food? Check your answer by tracing the energy in certain foods back to its source. For example, you might trace the energy in cheese like this: *cheese, milk, cow, grass* (a green plant). Trace such foods as fish, beef, pork, mushrooms, eggs, etc. Illustrate your findings for the class by using sketches or pictures cut from magazines.
6. Using reference books as a source of information, prepare sketches or models to illustrate how the shape of a cell is related to its specialized functions. In your study include such cells as red blood cells, white blood cells, skin cells, nerve cells, sensory cells, muscle cells, bone cells, and gland cells.
7. Plan a demonstration to test for the presence of chlorophyll in a leaf that is naturally red or copper colored. If your teacher approves the plan, carry out the demonstration.
8. Plan an experiment to see whether the leaves of a geranium plant will make foods and store starch when only artificial light is available to them. If your teacher approves the plan, carry out the test.

READING FURTHER

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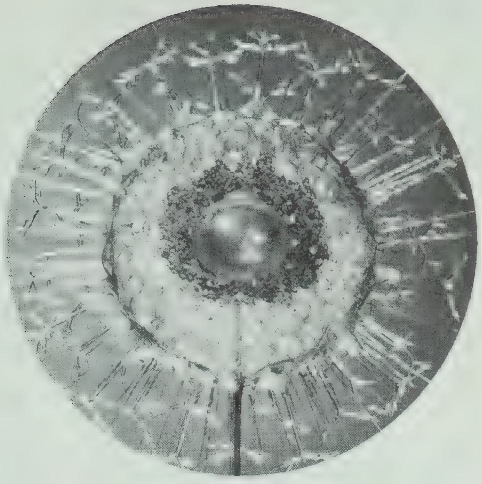
CHAPTER 4



The Organism

In previous lessons you learned that while organisms are similar in some respects, they are different in others. Some organisms are exceedingly small, but there also are giants in the plant and animal groups.

For example, the blue whale weighs over 100 tons. This is far heavier than any of the large dinosaurs of past ages. The giant redwood and sequoia trees of our west coast forest may rear themselves over 350 feet high. In addition to their remarkable size, these trees are also noted for being long-lived. Some of the sequoias appear to have been in existence for over 4,000 years.

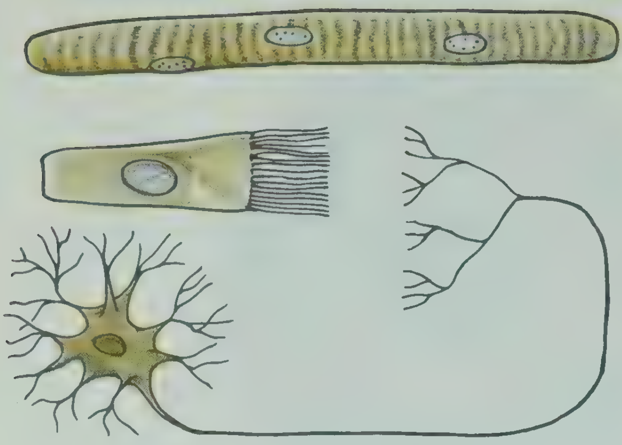
Large animals and large plants are not simple organisms like paramecia and algae. The bodies of these large animals and plants are made up of many cells. Groups of cells do special kinds of work. As you might guess, the cells that do one kind of work are not the same as the cells that do another kind of work. These groups of cells are specialized. This means that they do a particular type of work.

TISSUES, ORGANS AND SYSTEMS

In a large organism most of the cells are far removed from the body surface. Such cells are not like the free cells that can obtain food and oxygen from the surrounding water, and discharge wastes into the water. Rather, most of the cells in large organisms must depend upon other cells for the materials essential to life.

Cells and tissues. In the bodies of many complex organisms are various cells that have special functions. Fig. 4–1*A* shows one type of muscle cell found in the human body. You will see at once that this cell is rather elongated, or drawn-out in form. It is the type of cell that might be found in a muscle of the upper arm. Its main function is to contract, or shorten.

It takes a great many cells to make up a muscle of any size. These cells are all more or less alike, and all of them do the same kind of work. Together they make up what we call a ***tissue.*** Thus, the cells of a tissue are similar in *struc-*



4–1. (A) One kind of human muscle cell; (B) a gland cell from the stomach lining; (C) one type of nerve cell.

ture and *function*. When muscle cells function together, the entire muscle contracts. The muscle may exert a pull upon bones of the arm, and the arm moves.

For doing this kind of work, a muscle cell is quite effective. But note that the muscle cell is dependent upon other cells of the body for such things as food, oxygen, and waste removal. The muscle cell does only one job well, and that is to contract and produce movement.

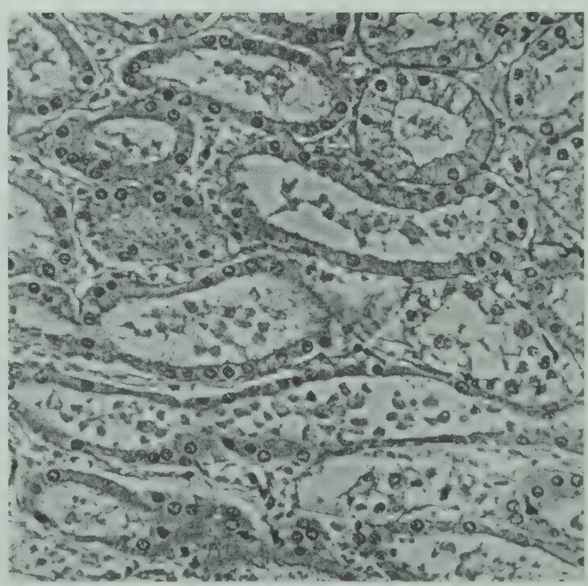
Two other special kinds of cells are also shown in Fig. 4–1. The gland cell secretes fluids that aid in the digestion of foods. Such cells are located in your stomach lining. A group of gland cells makes up a gland tissue. The nerve cell does the important work of carrying messages, and a group of nerve cells is called nerve tissue.

Now you may begin to realize that a single-celled organism is a "jack of all trades." There is only one cell to do many kinds of work. But in a more complex plant or animal there is a *division of labor* among the various kinds of cells. Each tissue does its own kind of work.

Tissues and organs. Division of labor does not end with the development of special tissues. In many complex organisms groups of tissues are combined to form ***organs***, such as the human stomach. An organ, then, consists of a group of tissues that work together to perform some special function. In the case of our stomachs, the special function is one phase of digestion. The tissues in the stomach wall that aid digestion include muscle tissue, nerve tissue, and gland tissue.

Organs and systems. In the more complex organisms, various ***systems*** are also recognized. These systems generally include groups of organs. Thus, in our own bodies the stomach is part of the digestive system, which is concerned with the general process of digesting foods.

Following this introduction, we can turn to some specific examples. These will include some of the simpler plants and animals. You will see, however, that special cells are developed by some of them, and in more complex types, we find organs and systems.



4–2. Kidney tissue. Note the similarity of cell structure. (*Walter Dawn*)

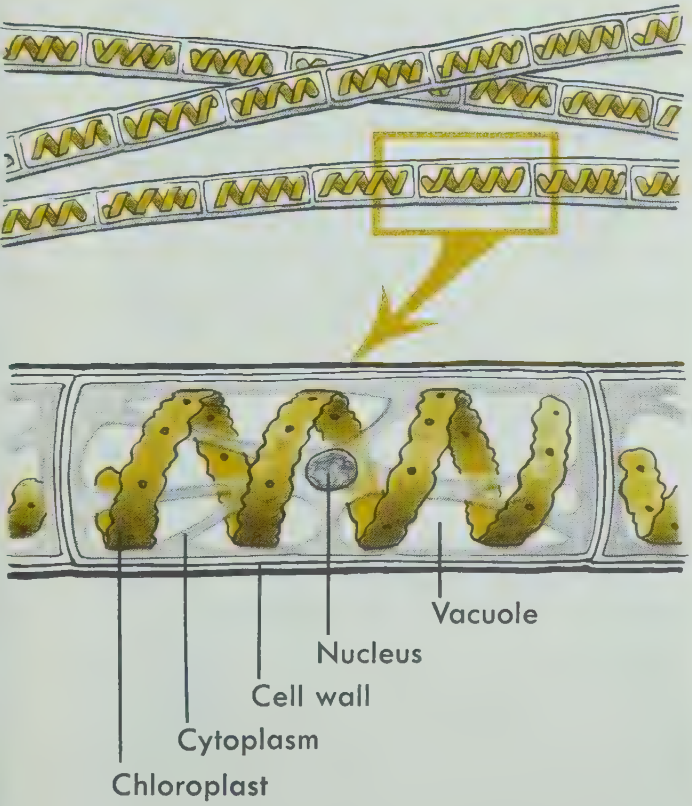
A MANY-CELLED ALGA

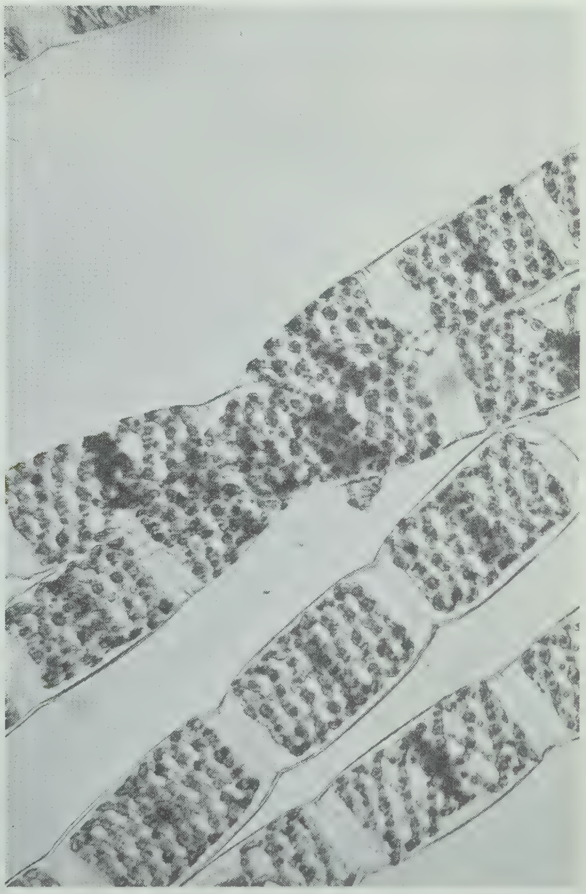
Previously, you have studied one or two single-celled algae. Let us now examine a type that has a number of cells. A good example is *Spirogyra* (*spy*-roh-jy-ruh), which is one of the pond scums you read about in Chapter 1. It consists of a colony of cells that grows end to end forming a filament, as shown in Fig. 4–3. You can study living specimens taken from a pond culture, or specimens that have been permanently mounted on microscope slides.

A SPIROGYRA FILAMENT Examine a *Spirogyra* filament with the aid of a microscope. Probably the first thing you will notice is that the cells are all very much alike. And indeed, each cell is in contact with the surrounding water, makes its own foods, and in a sense, "shifts for itself."

Now examine a single cell more closely under high power. Locate the cell wall. Just inside it is the cell membrane, which you may not see because it is so thin. Do you find a ribbonlike chloroplast that forms a spiral in the cell? Note the color of this chloroplast.

Near the center of the cell is a small, dense nucleus. Otherwise, most of the cell is occupied by a large vacuole. But cytoplasm is present. Some of this cytoplasm forms a layer all around the cell





4–3. *Spirogyra* grows as a colony of cells that forms a filament.

next to the cell membrane, and some of it is grouped around the nucleus, with strands extending outward to connect with the cytoplasm near the cell surface. The chloroplast is also a part of the cytoplasm.

Each cell of a *Spirogyra* makes food, grows, and is able to divide when it reaches full size. First, the nucleus divides, as shown in Fig. 3–7 on page 46. Then the rest of the cell divides through its short axis. So there are two cells in place of a single cell, and as the new cells grow, the filament gets longer.

Now and then a *Spirogyra* filament gets broken into two or more parts through accident or because some aquatic animal is feeding upon it. In this case, cells of the remaining pieces may grow, divide, and produce long filaments again. But *Spirogyra* does have another way of producing new colonies. It involves the development of special reproductive cells, and is described on page 125 of this book.

4–4. Green algae covering a boulder at the base of a waterfall. (*Walter Dawn*)

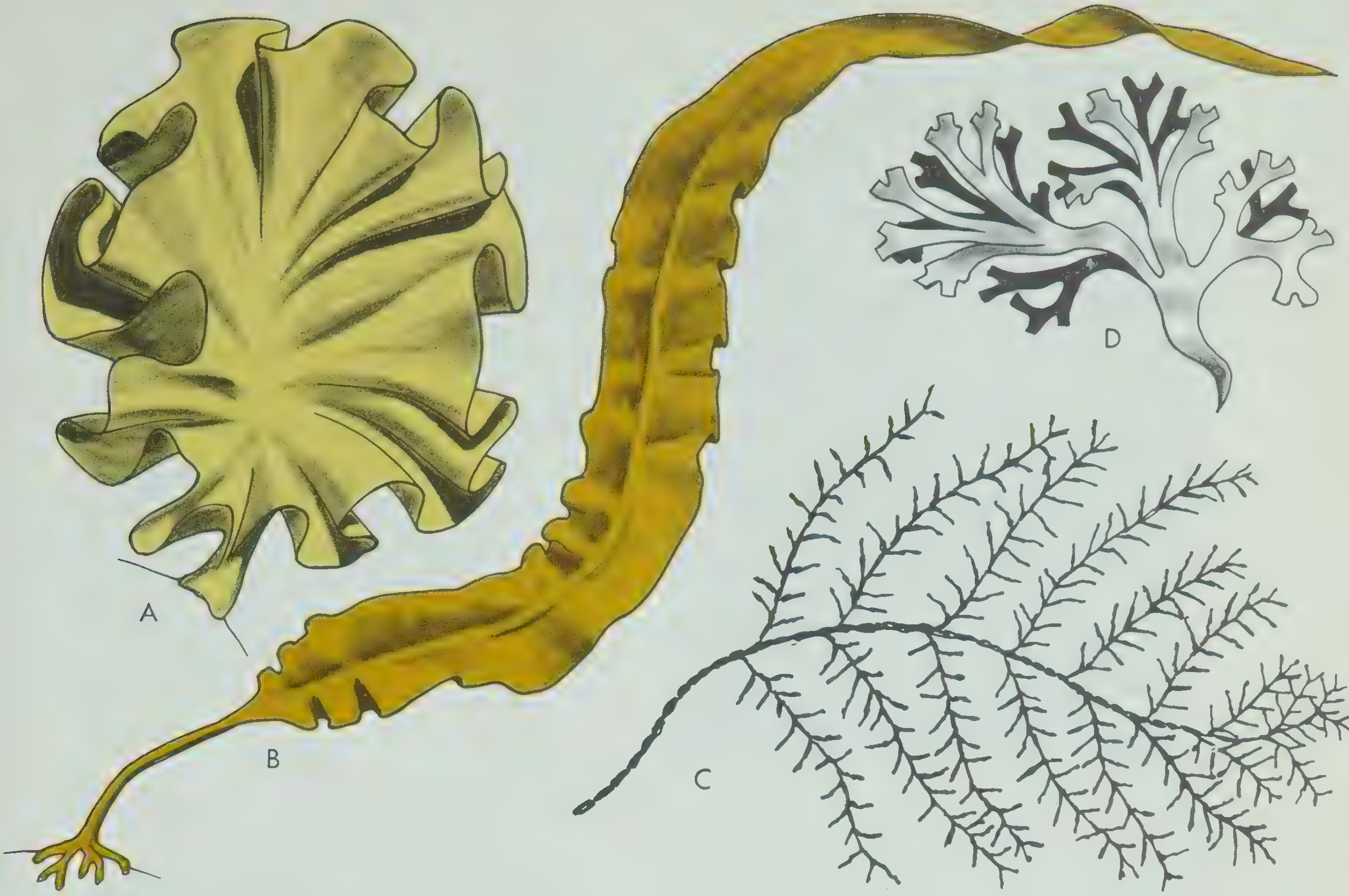
ANALYSIS. From what you have observed about *Spirogyra*, you know that it is a green plant, and lives as a colony of cells. Before leaving the subject, prepare answers to the following questions in your notebook:

1. Do the cells of a *Spirogyra* filament show any tendency toward division of labor? Give reasons for your answer.
2. What portion of a *Spirogyra* cell probably is the food-making center? What substance accounts for the color of this part of the cell?

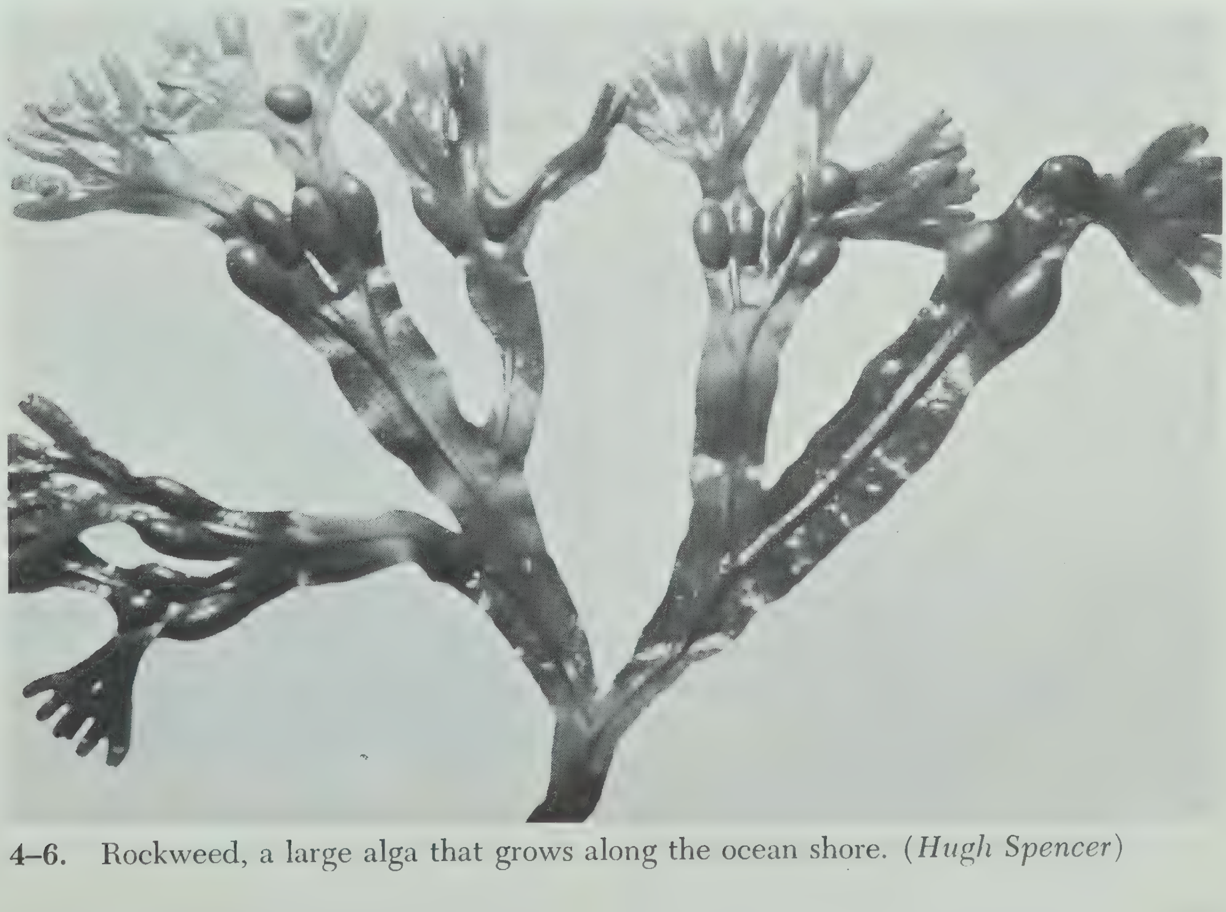
TYPES OF ALGAE

Spirogyra is one type of alga that grows as a filament of cells, and there are other types that are similar, as well as many single-celled algae. If you have kept an aquarium, you know that you sometimes have trouble with algae. They may grow and reproduce so fast that the sides of the aquarium and the water become greenish in color. The same problem relates to city water supplies in which the algae may cause an unpleasant odor or taste. Swimming pools and reservoirs can easily become filled with algal growths.

Collecting algae. If ponds or slow moving streams are nearby, it is usually simple enough to collect many kinds of algae. In some cases, they form "pond scums" on the water surface. (See Fig. 3–14.) Other types grow attached to rocks or pieces of wood at the shore line. You can easily collect samples of various types, as well as a supply of pond water. Keep your specimens in jars or culture bowls where they will get light from a window or lamp, but do not allow them to get too warm. Add



4–5. Diversity among algae: (A) *Ulva,* (B) *Laminaria,* (C) *Corallina* and (D) *Chondrus.*



4–6. Rockweed, a large alga that grows along the ocean shore. (*Hugh Spencer*)

pond water from time to time so that the cultures do not dry out. After a few days, you may find that your algae are increasing in numbers.

Single-celled algae. Many of the algae you are likely to find in aquariums are single-celled types. Such algae, of course, are very small in size. But when a lot of them are present, a green film appears on the aquarium glass. The water itself may look green. These small, simple algae are important, because all of them are food makers.

Algae from the sea. If you live near the sea, you probably have seen rockweeds. They are one type of seaweed, and they are algae. Rockweeds grow attached to rocks along the shore, and at low tide it is not difficult to get samples. They form massive growths that are composed of many cells. One type of rockweed is shown in Fig. 4–6.

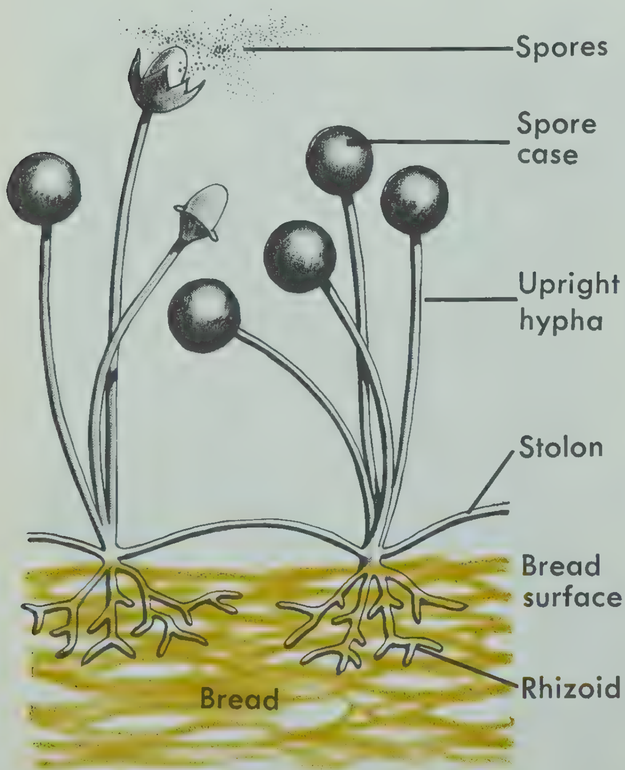
The body of a rockweed is called a ***thallus*** (*thal*-luss). For the most part, cells of the thallus carry on their own life activities independent of other cells. These rockweed cells contain chlorophyll, and are able to make their own foods. The thallus, however, is brown in color. This is because so much brown pigment is present that the green pigment cannot be seen.

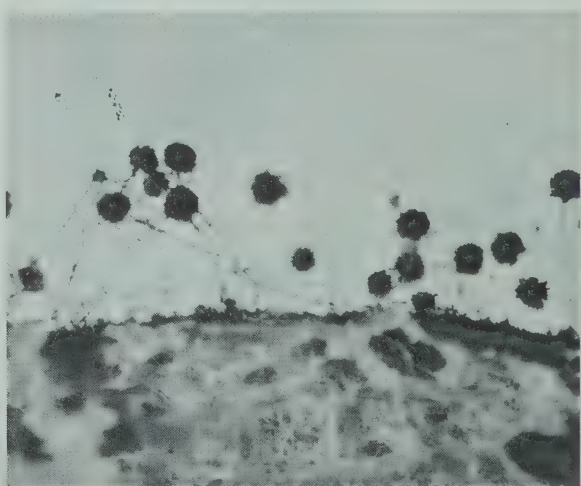
A rockweed has some cells that perform special functions. Some of these cells form a ***holdfast,*** which attaches the plant to a rock near the shoreline. Other cells form air-filled ***floats*** which hold the plant upright when it is covered by water at high tide.

THE MOLDS

Molds are one type of fungi, and as you know, fungi do not have chlorophyll. Therefore, molds are unable to make foods. But they find ready-made foods of many kinds, and as a result, they are likely to be very numerous. One well-known type is bread mold.

Bread mold. Since you do not care for moldy bread, you probably will





4–7. Can you identify the bread mold structures in the right-hand picture? (*Fleischmann Laboratories, Standard Brands, Inc.*)

conclude that some fungi are a nuisance, and such is indeed the case. In fact, many kinds of molds tend to destroy foods and other useful materials. If we keep such materials dry enough, or cold enough, molds generally will not attack them.

Bread mold is a fairly simple plant, as shown in Fig. 4–7. A plan for growing and studying this mold will be found on page 126. Bread mold consists of a branching, threadlike structure. Each branch is known as a ***hypha*** (*hy*-fuh), but there are three different kinds of hyphae (*hy*-fee).

Some of the hyphae that are called ***rhizoids*** (*ri*-zoids) extend down into the substance of the bread. Other hyphae known as ***stolons*** (*stow*-luns) are above the bread surface. They connect the various groups of rhizoids together.

After a few days some ***upright hyphae*** will develop. Tiny, ball-like structures form at their tips, and darken as they mature. These little balls are ***spore cases,*** and in them minute cells known as ***spores*** are being formed. When the spores are fully formed or mature, the spore cases break open, and thousands of spores are released to float with air currents, and finally come to rest on various surfaces. If a spore lands in a suitable spot for growth, it develops into a new mold plant.

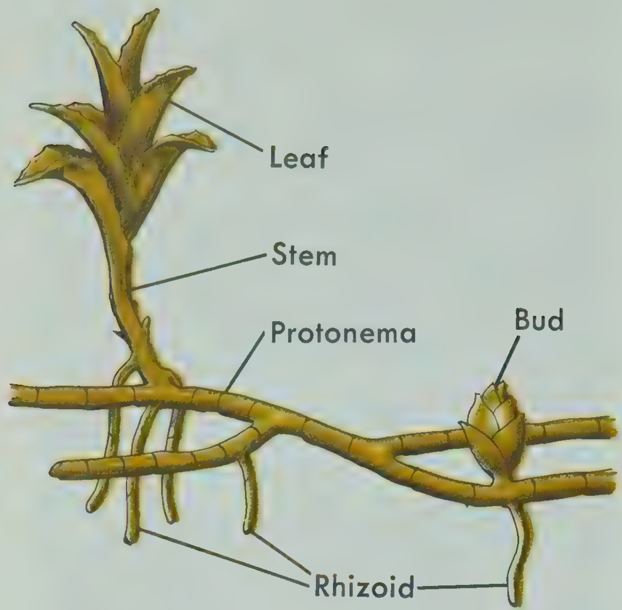
When spores are formed in the manner just described, reproduction is said to be ***asexual*** (*a*-sex-uall), which means without the formation of sex cells. But bread mold also has a ***sexual*** method of reproduction. There are two kinds of bread mold, which are called a ***plus strain*** and a ***minus strain.*** Sometimes a hypha of the plus strain develops close to a hypha of the minus strain. When this happens a cell forms near the top of each hypha. These two cells are

4–8. Cheese curing and aging room. Some fungi play an important part in cheese making. (*Switzerland Cheese Association*)

sex cells, and they unite to form a ***zygote*** (*zi*-gote). After a resting period the zygote develops a spore case and spores. The spores are liberated when they are mature, and each of them can develop into a new mold plant.

A MOSS PLANT

No doubt, you have seen moss plants many times. In moist places they often form a "carpet" on the soil surface. Compared with trees or garden vegetables, they are relatively simple plants, but they are more complex than the algae you have studied. As you know from your own observations, mosses are green plants.



4–9. A moss plant.

OBSERVATION OF A MOSS PLANT You probably can obtain samples of moss plants in your own neighborhood. The moist banks of a creek or pond are good places to look for them. Try to take out a single upright stem with its attached parts. It will look more or less like the diagram in Fig. 4–9. You will have to be careful in separating the plant from the soil, because some of its parts are delicate and easily broken.

The upright stem of a moss plant is easy to identify. On it you will find a number of small leaves. Both these leaves and the stems have cells that contain *chlorophyll.*

Now, observe that the stem grows from a branching structure called the ***protonema*** (*proh*-toh-*nee*-muh). In some mosses you will find the protonema largely or entirely above ground; in others it grows in the surface soil. Cells of the protonema may also contain chlorophyll. Here and there on the protonema you are likely to find ***buds.*** These buds grow and become stems that bear leaves. So you may find two or more upright stems growing from the same protonema.

See if you can find some of the slender, rootlike rhizoids. They arise near the base of a stem, and extend down into the soil. They are brownish in color. Rhizoids hold the plant in place, and absorb water containing mineral compounds from the soil.

ANALYSIS After you have examined the parts of a moss plant, prepare answers to the following questions in your notebook:

1. What parts of the moss plant that you examined appear to be food-making centers? Why do you think so?
2. In what other type of plant have you found rhizoids that serve a similar purpose?
3. Do you think a moss plant is more complex than a *Spirogyra*? Than a bread mold? Give reasons for your answers.
4. What do you think would happen to a moss plant if the surface soil dried out and stayed that way for several weeks?

LIVERWORTS AND MOSSES

Liverworts. Liverworts and mosses belong to the same general group of plants. You usually find liverworts either in the water, or in very moist places along the banks of a stream. They develop a bladelike type of thallus that lies close to the soil. Like the mosses, liverworts are green plants, and are able to make foods.

The mosses. Mosses generally grow on soils that stay moist a large part of the time. They are more complex than

4–10. The thallus of a liverwort. (*Walter Dawn*)

the algae, as you have seen. But mosses do not develop the *vascular tissues* that are found in higher plants. Vascular tissues are made up of cells that specialize in transporting liquids.

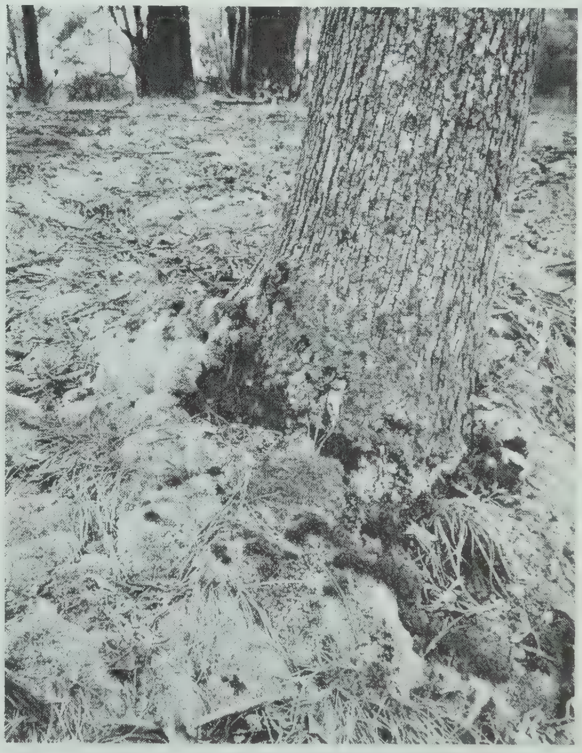
Because mosses form buds that grow into upright stems, you are likely to find a whole group of moss plants attached to the same protonema. As new buds and stems form, the moss growth may become a sort of natural carpet on the soil surface.

Reproduction in mosses. Mosses often have a sexual method of reproduction. Male and female ***sex organs*** are developed at the tips of some stems. An ***egg cell*** forms in each female organ. Each male organ produces a number of ***sperm cells.*** The sperm cells are small and bear tail-like flagella; they are able to swim through films of water that cover the moss plants. When a sperm cell reaches an egg cell, the two unite to form a *zygote.* This union of male and female sex cells is called ***fertilization*** (*fer*-til-uh-*zay*-shun).

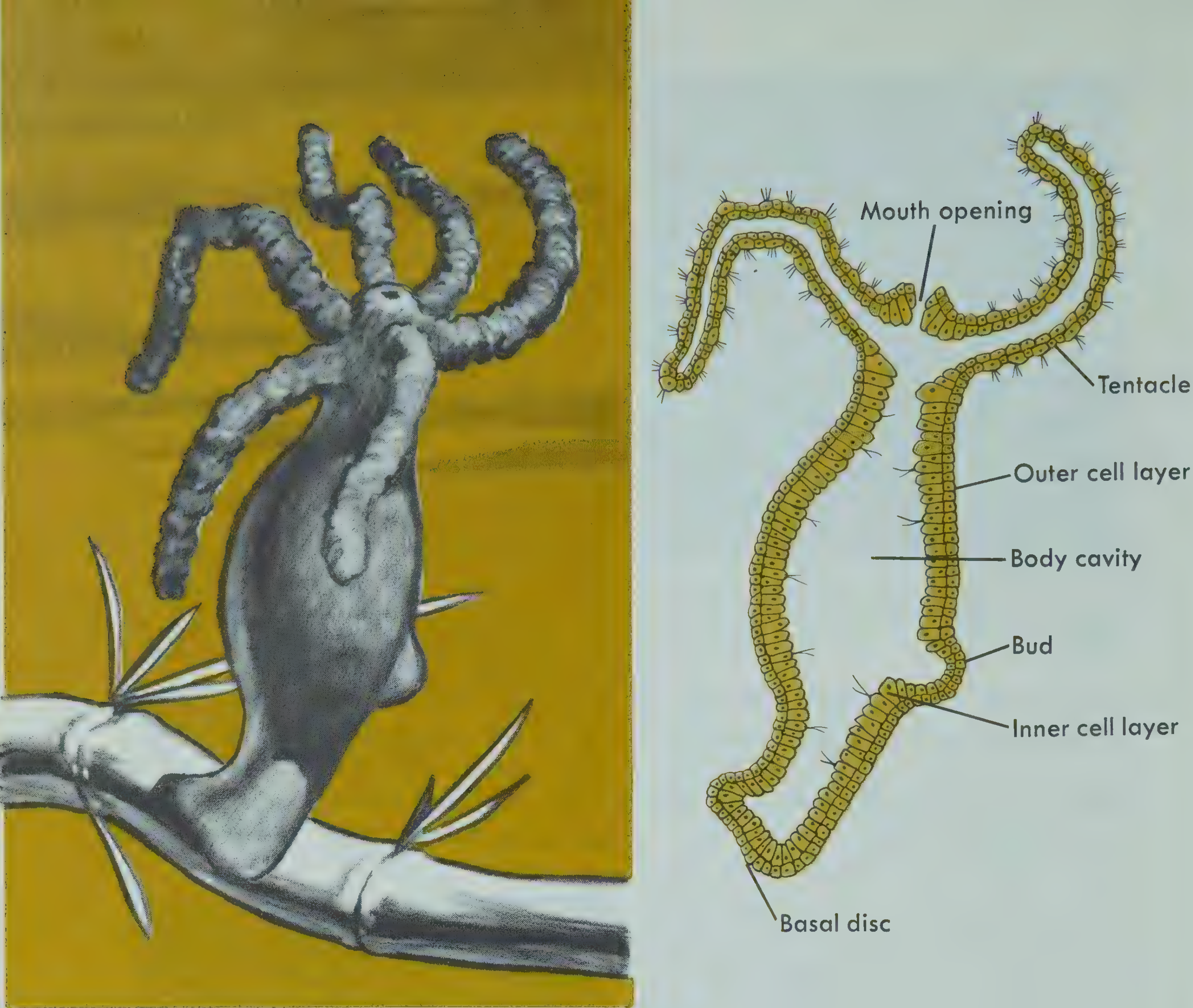
This zygote divides to form more cells, and develops a structure which remains attached to the parent moss plant. Within this structure spore cells are produced. When the spore cells are mature, they are liberated, and if they come to rest in suitable places, each of them can develop a new moss protonema. In its turn, the protonema gives rise to buds, stems, and rhizoids.

HYDRA: A SIMPLE ANIMAL

A good example of a fairly simple animal, that has some division of labor among the cells of its body, is provided by *Hydra.* This little animal is a relative of the corals that live in the sea, but hydra is found in cold streams and ponds. Sometimes hydra is attached to



4–11. On your way home from school today look for a moss-covered area like the one pictured above. (*Walter Dawn*)



4–12. The drawing on the left shows a hydra in its natural state while the right-hand drawing shows structures of a hydra in detail.

the stems and leaves of water plants. Actually, there are several kinds of hydra. Although they are large enough to see, you need a hand lens or the low power of a microscope to study them in detail.

OBSERVING A HYDRA If you have a culture of living hydra, put a few drops of water containing one of these animals in a watch glass, and examine your specimen under the low power of a projector or microscope. What you see will look like the left-hand drawing of Fig. 4–12.

Note how the body is attached at its *base,* how it can lengthen and shorten, and how the armlike tentacles move about. The mouth opening is at the top of the body column. You can see through the body wall and observe a large body cavity. Only the mouth connects with the exterior.

Perhaps you can see tiny groups of short bristles on the tentacles. They mark the location of stinging cells, which are used in capturing the small animals that serve as food. The tentacles maneuver the captured organisms into the mouth opening. Foods in

4–13. A hydra catching a waterflea. (*Eric Gravé from Photo Researchers*)

the body cavity are acted upon by digestive enzymes which are secreted by cells lining the cavity. As food is digested, the usable products are absorbed by these cells.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Hydra is a many-celled animal. Have you seen any evidence that there is a division of labor among these cells? Explain.
2. What evidence indicates that some of a hydra's cells behave like muscle cells?
3. Hydra's body cavity has only one opening: the mouth. How do you suppose that a hydra gets rid of the solid wastes that accumulate in its body cavity?

STRUCTURE AND FUNCTION IN HYDRA

If you have observed a living hydra, you know that it has a single large body cavity, with only a mouth opening connecting with the outside. The animal's tentacles are arranged in a ring around the mouth opening. Digestion of foods is begun in the body cavity. From this cavity wastes can be discharged.

Hydra's body wall. A hydra's body wall consists of an outer cell layer and an inner cell layer. Between these cell layers is a thin sheet of material that is largely noncellular. The arrangement of these layers is shown in the right-hand drawing of Fig. 4–12. At the lower end of the body column is the *base*, by which a hydra is attached to plants or other objects in the water.

A hydra's outer cell layer contains a number of cell types, which may be described as follows:

Stinging cells, which are found all over the body column, but are most numerous on the tentacles.

Cells which form an outer surface, and at the same time, are able to contract and produce movement.

Sex cells, both male and female.

Nerve cells, which form a sort of network among the cells that surround the mouth opening.

Sensory cells, which are specialized to receive stimuli.

Formative cells, which are small cells that develop into other kinds of cells when they are needed for growth or repair.

A hydra's inner cell layer is in contact with the liquid that fills the body cavity. In this inner cell layer are the following cell types:

Cells which serve to digest foods, but also are able to contract and produce movement.

Two other types of cells that are concerned mainly with digestion.

Nerve cells in the area around the mouth opening, but not as many as in the outer layer.

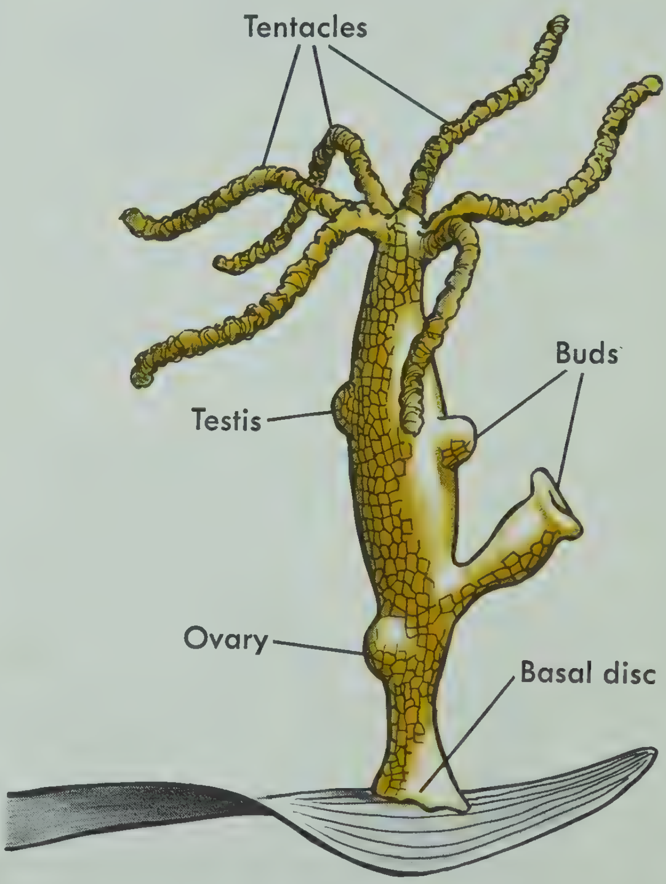
Sensory cells, greater in number than in the outer layer.

Formative cells, fewer in number than in the outer layer.

Division of labor. From what has been stated here, you can see that a hydra has at least a partial division of labor among its cells. The stinging cells, nerve cells, sensory cells, and sex cells all have special functions. You might say that primitive tissues exist or are partially formed. The network of nerve cells makes up such a primitive tissue. Cells of the inner layer function partly in digestion and partly in movement. The outer layer has cells that form a surface on the outside of the body, and also are able to contract and cause movement.

How hydra reproduces. In observing specimens of a hydra, you are likely to see at least one with a *bud* attached to the body column. In fact, two or more buds may be seen on some specimens. A bud grows, and it develops a mouth opening and tentacles of its own. Then it breaks away from the parent hydra and lives a separate existence. This is, of course, an *asexual* type of reproduction.

Hydra also has a sexual method of reproduction. Male and female sex organs are developed from *formative* cells of the outer layer. The male or-



4–14. There are two methods of reproduction in the hydra: sexual and asexual. Note the reproductive structures shown in the above drawing.

gans, known as ***testes*** (*tes*-teez), appear on the upper part of the body column. The female organs or ***ovaries*** (*oh*-vah-reez) form farther down on the body column near its base.

Each testis produces numerous small sperm cells, which break free and swim about in the water. An ovary produces a single, large egg cell, which for the time being remains attached to the ovary. If by chance a sperm cell swims to the egg cell, the two cells will unite. The result is a fertilized egg cell or zygote.

The fertilized egg cell divides to form more cells, and an ***embryo*** (*em*-bree-oh) is produced. An embryo is a developing organism. A protective covering is secreted around this embryo. The embryo now breaks free and drops to the bottom of the pond. Here it may lie in a *resting state* for some time. Later on, the protective covering falls away, and the embryo develops into a new hydra.

AN EARTHWORM

A hydra has no backbone. Animals without backbones are called ***invertebrates*** (in-*ver*-tuh-brates). A lot of other animals that you know belong in this same group. Among them are the familiar earthworms. Earthworms, however, are a good deal more complex than hydras.

OBSERVING AN EARTHWORM'S EXTERNAL STRUCTURE Either a living or a preserved earthworm may be used to study its external structure. Notice that the body is divided into a large number of ***segments.*** The head end is somewhat thicker than the tail end. Turn your specimen over and locate the ***mouth opening*** on the underside of the first segment. Also locate the ***anal*** (*a*-nul) ***opening*** in the last segment, through which solid wastes are discharged. An earthworm has a digestive canal which extends through the body from the mouth to the anal opening.

4–15. Can you see the segments of this earthworm? (*Walter Dawn*)

Next, feel along the sides of the worm, or examine the sides with a hand lens. You will find rows of short bristles that are called ***setae*** (*set*-tee). Most of the worm's segments bear *four pairs* of these setae. They extend outward from the body wall, and they are controlled by muscles in the body wall.

Did you ever see a robin pulling on one end of an earthworm that has its other end down in a burrow? The robin usually gets the worm, but not without a struggle. The worm's setae enable it to hold on to the walls of the burrow,

and sometimes the worm escapes. In calmer moments, an earthworm uses its setae in crawling. And incidentally, the worm makes burrows by eating its way through the soil. It gets nourishment from decaying plant and animal materials in the soil, and it deposits its solid wastes above ground near the entrance of its burrow.

Your specimen may have a bandlike thickening of its body wall about one-third of the distance from head to tail. This thickening is the ***clitellum*** (kli-*tel*-um) which is involved in reproduction. Some kinds of earthworms have this structure and others do not. There are also numerous pores that open through the body wall, but most of them are very small and may not be seen.

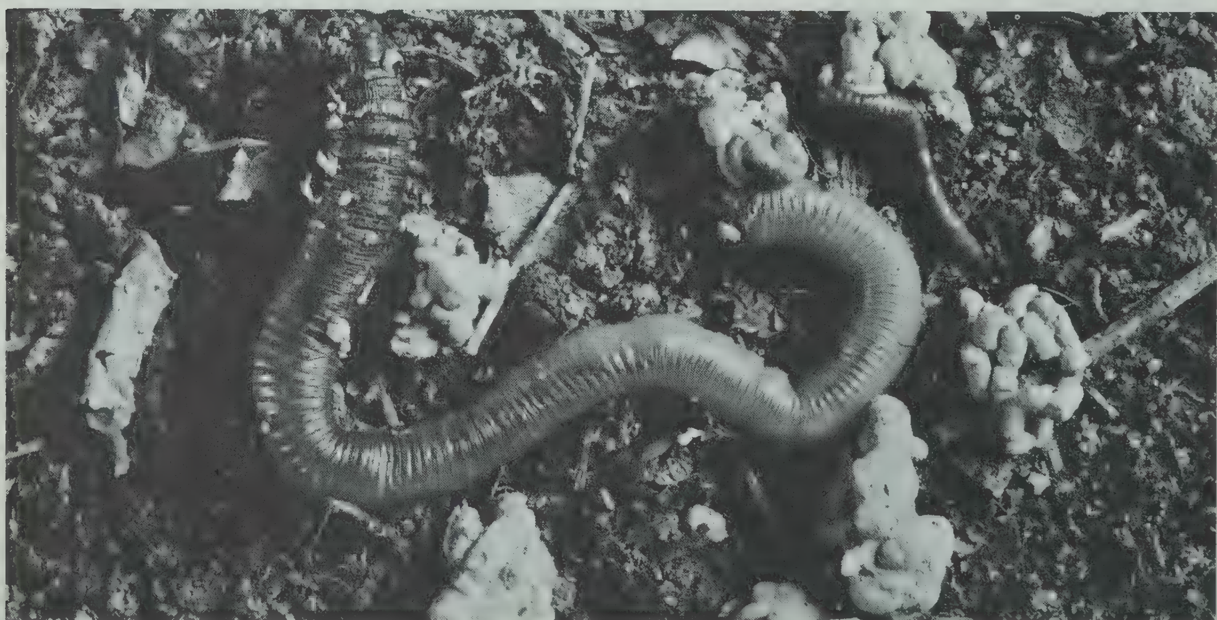
ANALYSIS After you have examined an earthworm's external structure, prepare answers to the following questions in your notebook:

1. Why are earthworms and their relatives called "segmented worms"?
2. Would you expect to find a lot of earthworms in a soil that contains little or no organic material? Give reasons for your answer.
3. How do you suppose an earthworm gets the oxygen supplies an animal must have?

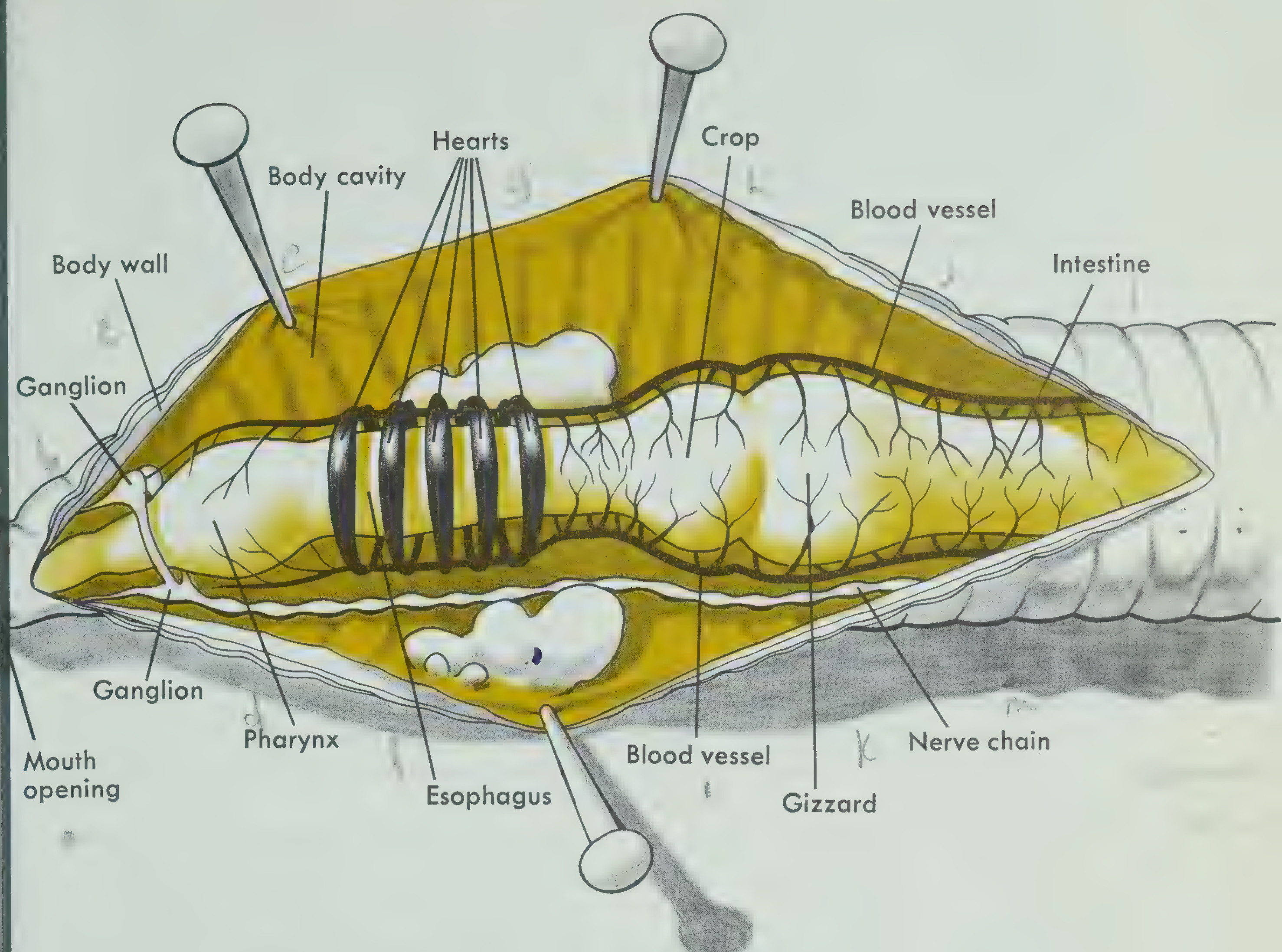
EARTHWORM STRUCTURES

A life in the soil. To live successfully, earthworms require a moist soil, and one that contains suitable food materials. When the surface soil begins to dry out, earthworms burrow deeper. On the other hand, when heavy rains fall, they may emerge from their burrows and crawl about on the surface. What people call "night crawlers" are simply earthworms that have come out of their burrows at night.

The earthworm's habit of depositing solid wastes or *castings* on the surface of the ground is of some importance. By so doing, they tend to bring up the smaller soil particles and spread



4–16. The earthworm deposits its solid wastes as castings above the ground near the entrance to its burrow. (*Grant Heilman*)



4–17. An earthworm dissection.

them over the top of the soil. This does no harm insofar as gardens are concerned. But earthworm castings in the form of little piles of earth are certainly a nuisance on golf greens.

Internal systems. On page 128 of this book you will find directions for dissecting an earthworm and studying its internal systems. We are now dealing with an animal that not only has well developed tissues, but organs and systems as well.

Fig. 4–17 shows structures in the head end of an earthworm. Notice that the body is divided into segments internally, as well as externally. A body cavity lies between the body wall and the digestive canal.

Fig. 4–17 also shows the main structures of an earthworm's digestive system. Soil containing food material enters the mouth cavity, and then passes into a short ***pharynx*** (*fahr*-incks) which is a swallowing organ. Then the materials pass through a longer ***esophagus*** (uh-*sof*-uh-gus) to a pouchlike ***crop.*** Next comes a grinding organ or ***gizzard,*** which has heavy, muscular walls, and behind it lies the ***intestine*** (in-*test*-un) which leads back to the anal opening. Thus, the digestive system includes a number of organs, and makes up a continuous canal that extends from one end of the body to the other end. Find the organs of the digestive system in the above diagram.

The organic material in soil that an earthworm has swallowed is acted upon by digestive enzymes. These enzymes come from cells in the lining of the digestive canal. Digested food materials are absorbed by blood vessels in the wall of the intestine.

Structures of the circulatory system may be seen in Fig. 4–17. The two largest blood vessels lie just above and just below the digestive canal. Five pairs of so-called "hearts" connect these blood vessels in the region of the esophagus. The "hearts" and the blood vessel above the digestive canal contract to maintain a flow of blood. There are three smaller blood vessels (not shown in Fig. 4–17) in the lower part of the body cavity. And there are various branch blood vessels that carry blood to the wall of the digestive canal, and to the body wall. It is through branch blood vessels in the body wall that this animal obtains supplies of oxygen.

The blood of an earthworm consists of a basic fluid or ***plasma*** (*plaz*-muh) which contains a red pigment. There are blood cells, but they are without pigment. The spaces of the body cavity also contain a fluid, but this fluid is colorless. Some colorless blood cells are also found in the fluid of the body cavity.

The ***nerve chain,*** lying along the lower side of the body cavity, is one of the main control centers of the nervous system. This nerve chain is really a *double* structure, and it gives off branch nerves to various parts of the body. As can be seen in Fig. 4–17, there is a thickening at the front end of the nerve chain, which represents a pair of ***ganglia*** (*gang*-lee-uh). These ganglia are connected with another pair which lie above the digestive canal and make up a sort of "brain."

The function of the nervous system is to coordinate activities of the various body systems. The body muscles, for instance, must work together if the worm is to burrow in the soil or crawl upon the surface.

Most segments of an earthworm's body contain a pair of coiled tubes, whose ends pass through the body wall and open to the outside through pores. Wastes pass out of the body through these tubes.

An individual earthworm has both female sex organs or ovaries, and male sex organs or testes. However, an earthworm does not fertilize its own egg cells. Two worms come together, and sperms of each worm fertilize egg cells of the other worm. Each worm then secretes a capsule or *cocoon* which contains its fertilized eggs. The cocoon slides over the head end of its body, and remains in the soil until the young worms have come from the eggs.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. algae	Nongreen plants.
2. egg cell	Simple green plants.
3. embryo	A group of organs working together.
4. fungi	A group of tissues working together.
5. organ	Blood fluid.
6. plasma	Female reproductive cell.
7. sperm	Male reproductive cell.
8. system	A developing organism.

B

1. tissue	A structure formed when male and female sex cells unite.
2. zygote	Animal without a backbone.
3. fertilization	Female reproductive organ.
4. invertebrate	Male reproductive organ.
5. nerve cell	Bandlike structure on the outside of an earthworm's body.
6. ovary	A group of cells of the same type.
7. testis	Process by which two reproductive cells unite.
8. clitellum	Type of cell that carries messages.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Blue whales reach sizes greater than any of the large dinosaurs of the past.
2. Some sequoia trees appear to have lived for over 4,000 years.
3. The cells of a tissue are very much alike in structure and function.
4. Some muscle cells pull when they contract, while others push as they relax.
5. Tissue cells are quite independent of other kinds of cells.
6. Paramecium cells better illustrate what is meant by "division of labor among cells" than do the cells of a hydra.
7. Certain cells in the stomach lining are called gland cells.
8. The stomach, small intestine, and large intestine are parts of a system.
9. *Spirogyra* is an example of a single-celled alga.
10. *Spirogyra* may reproduce by means of special reproductive cells.
11. The seaweed known as rockweed belongs to the plant group called the fungi.

12. Even though a living rockweed appears brown, it is likely to contain chlorophyll.
13. Bread molds commonly contain chlorophyll.
14. Bread molds commonly reproduce by means of special cells called spores.
15. Reproduction by spores takes place in the case of paramecium.
16. Algae are considered to be more complex than mosses.
17. Moss plants sometimes develop from egg and sperm cells.
18. An embryo is formed when fertilization takes place.
19. A hydra may capture food by means of stinging cells on its tentacles.
20. A hydra has a mouth and an anal opening.
21. The formative cells of a hydra can change into other types of cells.
22. Ovaries are structures that develop sperm cells.
23. Two zygotes unite to form an egg cell.
24. An earthworm is an invertebrate.
25. An earthworm obtains food by eating soil.
26. Earthworm blood cells contain a red pigment.
27. An earthworm has waste removal parts in nearly every segment of its body.
28. In earthworms the sexes are separate. That is, some individuals are males, and others are females.

DISCUSSION QUESTIONS

1. Do large organisms have larger cells or just a greater number of cells than small organisms? How could you find out for sure?
2. In the statement, "The cells of a large plant or animal must depend upon other cells to provide them with the essentials of life," what is meant by "the essentials of life"?
3. In terms of what you understand about muscle structure and function, explain the statement, "Muscles can pull, but cannot push."
4. In what ways are gland tissue, muscle tissue, and nerve tissue alike? Different?
5. In what ways is a single-celled organism a "jack-of-all-trades"?
6. Define "division of labor," and give examples from the human body.
7. How is the structure of algae and fungi similar? Different?
8. Explain how growth takes place in algae and fungi. Also, explain how they obtain food and reproduce.
9. Distinguish between asexual and sexual reproduction.
10. Of what importance is a knowledge of algae to man? A knowledge of fungi?
11. How might the growth of algae be prevented in an aquarium?
12. What is the difference between growth and reproduction?

13. What environmental conditions are necessary for mold spore germination?
14. How does a moss plant live and grow?
15. Is it correct to say that tissues exist in algae, mosses, hydra, or earthworms? What about organs? Systems? Explain your answers.
16. In what ways is an earthworm more complex than a hydra?
17. In what ways are earthworms beneficial to other organisms?

THINGS TO DO

1. Using sketches or pictures cut from magazines, prepare a bulletin-board display to illustrate the idea that plants and animals vary in structure from simple to complex.
2. Prepare models of clay or plasticene to illustrate the structure of a cell, a tissue, an organ, and a system.
3. Write a short report comparing the ways in which a specialized cell is dependent upon other cells, with the ways in which a working man in a factory is dependent upon other kinds of workers in that factory.
4. Make a model or prepare sketches to show how the muscles of your upper arm are attached to arm and shoulder bones and how they work to bend and straighten the lower arm.
5. From colored construction paper, cut out shapes to illustrate the various stages in the life history of an alga, a fungus, and a moss. Label each stage, and mount them in sequence on the bulletin board.
6. Using pictures, prepare a display to illustrate the two major animal groups: vertebrates and invertebrates.
7. Observe an earthworm while it is moving. Write a short report to explain how the muscles must be arranged in the body to make movement through soil possible. Remember that muscles can only pull.

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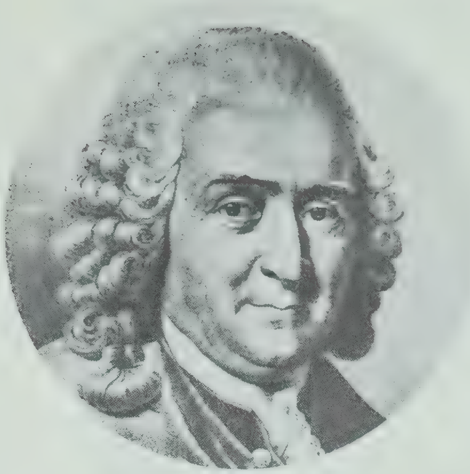


CHAPTER 5

Plant and Animal Diversity

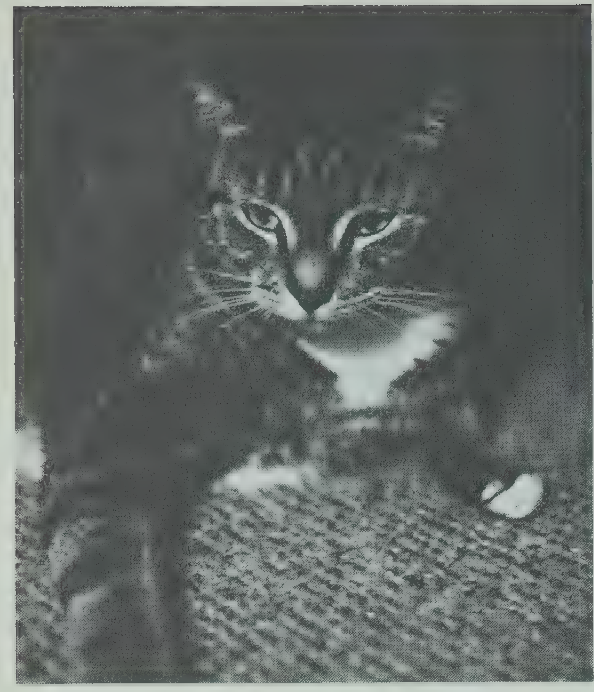
There are many kinds of plants and animals in our world. Men began to study them centuries ago. Travelers brought back tales about the living things found in foreign lands. Men learned to write, and among other things, they began to describe the various organisms they observed. In order to understand what kind of organism was being described, it became necessary to have names for the different plants and animals.

A CONFUSION OF NAMES

So men began to give names to living things. But these men spoke different languages, and they lived in various parts of the world. A plant or animal was quite likely to have one name in one country, and a different name in another country. This led to confusion after writing and printing came into use, and men began to travel more widely. Students of plants and animals could not be sure what students in another land were writing about.

Even today, some of this confusion exists among people who are not scientists. For example, a common type of maple tree in eastern North America is called the red maple by some people. To others it is known as the swamp maple, water maple, scarlet maple, or soft maple. In the same way some people call a well-known North American animal a woodchuck, but others call it a groundhog or a marmot.

The scientific name. To avoid the sort of misunderstanding that can result from a confusion of names, the eighteenth century Swedish scientist, Linnaeus, (opening photo Chapter 5), proposed a new system of naming organisms. In this new system every kind or ***species*** (*spee*-sheez) of organism was given a scientific name made up of two parts. The first part of the name was the ***genus*** (*jee*-nus), or group of *related species* to which it belonged. The second part was the name of the particular species or kind of organism.

5–1. The common house cat, *Felis domestica,* and the mountain lion, *Felis concoler,* belong to the same genus but are of different species. (*E. Tamiso (left) and Tommy Lark (right) from Photo Researchers*)

Thus, man has the scientific name *Homo sapiens. Homo* is the name of the genus, and the first letter of the genus is always capitalized. *Sapiens* is the species. The first letter of the species is always in lower case. Such a scientific name is either made up of Latin words, or words that have been given Latin endings. The Latin names are usually descriptive. For example, *Homo* means "man," and *sapiens* means "wise."

Here are some other well-known examples:

The common cat: *Felis domestica*

The common dog: *Canis familiaris*

A wolf: *Canis lyacon*

A red maple tree: *Acer rubrum*

A peach tree: *Prunus persica*

A sweet cherry tree: *Prunus avium*

Notice in these examples that the dog and the wolf belong to the same genus. This means that they are quite closely related. The peach tree and sweet cherry tree are also members of the same genus; they too are closely related.

Classification groups. A species, then, is made up of individuals that are all similar in structure, just as house cats are all more or less alike. But notice that the members of a species are not *identical.* Some cats are black and white, some are gray and white, some have short hair, some have long hair, some are large, and some are small. Even identical twins are not exactly alike in all of their characteristics. The differences are called *variations,* and such variations are very important when biologists try to develop better breeds of plants and animals.

You have also seen that two or more closely related species are grouped together in a genus. Naturally, members of a genus are likely to show a wider range of variation than members of a species. In the same manner, related genera are grouped together to form a ***family,*** related families are grouped to

Kingdom	Phylum	Class	Order	Family	Genus	Species	Common name
Animal	Chordata	Mammalia	Primates	Hominidae	*Homo*	*sapiens*	man
Animal	Chordata	Mammalia	Carnivora	Felidae	*Felis*	*domestica*	cat
Animal	Chordata	Mammalia	Carnivora	Canidae	*Canis*	*familiaris*	dog

form an ***order,*** and related orders are grouped to form a ***class.*** Finally, related classes are grouped to form a ***phylum*** (*fy*-lum), and related phyla make up a ***kingdom*** such as the ***Animal Kingdom.*** At the kingdom level you find a lot of variation; for instance, a grasshopper does not look much like a polar bear, but both are members of the Animal Kingdom.

In the above table, you can see how this system applies to several familiar animals. All of these animals, of course, belong to the same kingdom. But observe that they also belong to the same phylum and the same class, and that two of them belong to the same order. However, families and genera are different for all of them. While members of a phylum or class have some characteristics in common, they also may have striking differences.

INDIVIDUAL DIFFERENCES

Having learned that the members of a species differ from one another, you may wish to observe some of the variations. Probably many of them have escaped your notice in times past, simply because you were not on the lookout for them. You can make a start by studying a group of lima bean seeds, or any other fairly large seeds.

Under the right conditions, a lima bean seed can sprout and grow into a new plant. A seed is really a plant embryo enclosed in a seed case. So if you observe a random sample of bean seeds, you can find out whether differences exist at this early stage of development.

VARIATION IN BEAN SEEDS Begin by making a random selection of 50 lima bean seeds. This means that you do not pick out the seeds, but take the first 50 that come out of the bag or box. Using a millimeter rule, measure the length of each seed. Prepare a data sheet in your notebook, like the following sample, and record your findings.

Seed number	Length in millimeters
1.	
2.	
3.	
Etc.	

When you have recorded all of your data, calculate the average seed length.

SPROUTING SOME NEW PLANTS Now suppose you want to know whether the new plants that come from seeds vary. Do all of them sprout at the same time? Do they grow at an equal rate?

You can get some answers by sprouting about 20 corn seeds that are selected at random. Plant the seeds in a single container of soil located on a

window shelf. Be sure that all of the seeds are planted at the same depth and spaced about three inches apart. Keep the soil moist, but not soaking wet. New plants should begin to push through the surface in a few days.

Prepare a data sheet in your notebook as follows:

Day	Numbers of the new plants
4. 5. 6. Etc.	

As the new plants appear, give each one its own number, and record the numbers in the appropriate column of the data sheet. At the end of three weeks, measure the heights of the various plants, and record your findings on another data sheet like this one:

Plant number	Height at three weeks
1. 2. 3. Etc.	

ANALYSIS When you have finished these observations of seeds and sprouting, prepare answers to the following questions in your notebook:

1. What was the average length of your lima bean seeds? How many seeds were longer than average? How many were shorter?
2. Do you suppose that a random sample of lima bean seeds would show differences in weight? How could you find out?
3. Did all of your corn seeds sprout? Did they all appear above ground at the same time? To what extent did all of them have an equal opportunity to sprout?
4. What was the average height of the new corn plants after three weeks? The maximum height? The minimum height?
5. In the light of your findings, of what value is "the average" when you are studying a species?

HUMAN REACTION TIME All humans are members of the same species, but you can easily see that they vary in many ways, including height, weight, and hair color. They also vary in what they can do. For example, they vary in *reaction time,* which represents the speed with which human muscles can react.

5–2. How fast is your reaction time?

Student number	1st trial	2d trial	3d trial	4th trial	Average	age	sex
1.							
2.							
3.							
Etc.							

A simple test of reaction time can be arranged. One student should hold his thumb and index finger one inch apart, as if he were about to pick up an object. Another student should hold a foot ruler with the one inch end just above the waiting fingers. When the latter student drops the ruler, the other student catches it between his thumb and index finger as quickly as he can. Perhaps he will catch it at the five-inch mark, but if his reaction time is slower, he may catch it at the seven-inch mark. The student knows what he is to do, and though he watches the ruler all the time, he does not know just when it will be dropped.

You should have at least four trials for each person tested. Then compute the average result for each person. Prepare a data sheet in your notebook like the one shown at the top of this page.

ANALYSIS When you have entered all of your data for this test of reaction time, prepare answers to the following questions in your notebook:

1. Do the data indicate that people show differences in their reaction time? Explain.
2. Were there any differences that seemed to be related to age? If so, what were they?
3. Were there any differences that seemed to be related to sex? What evidences do you have?

THE ANIMAL PHYLA

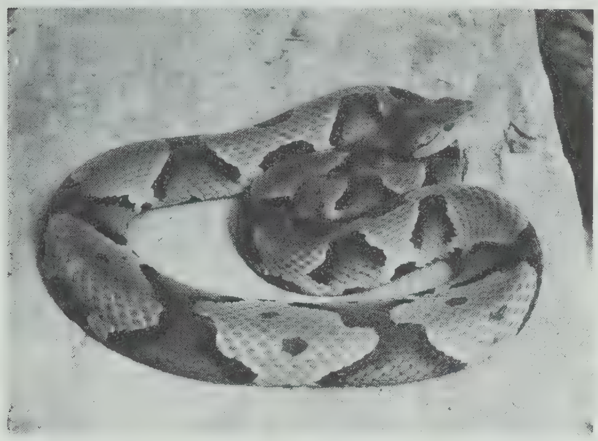
Let us now get acquainted with some of the important animal groups that are dealt with in this book. The list is arranged so that the higher or more complex types are given first.

The vertebrates. The ***vertebrates*** (*ver*-tuh-brates) are all animals with backbones. They are members of the same phylum. The following are classes of vertebrates:

1. ***Mammals*** (*mam*-m'ls). These animals are warm-blooded and can remain active in cold weather. Their body temperatures are not affected when temperatures around them change. They have hair as an outer covering. They breathe through lungs. Mammals include such types as kangaroos, moles, bats, cats, wolves, seals, squirrels, woodchucks, muskrats, rabbits, horses, cattle, deer, apes, monkeys, and whales.
2. ***Birds.*** Like mammals, birds are warm-blooded. Birds have feathers as their body covering. They breathe through lungs. Among them are such types as loons, herons, ducks, geese, pigeons, quail, parrots, hawks, owls, jays, crows, house sparrows, thrushes, and robins.
3. ***Reptiles*** (*rep*-tils). These vertebrates are cold-blooded, and become inactive in cold weather. Their body temperatures go up or down as the temperature around them changes. They have outer coverings of scales and plates. Members of the group include

5–3. Diversity among mammals. Top left, kangaroo; top right, chimpanzee; bottom, water bat. (*Australian News and Information Bureau; Toni Angermayer from Photo Researchers; Sdeuard Bisserot from Photo Researchers*)

5–4. Diversity among birds. Left, Adelie penguin; top right, hummingbird; bottom right, the flightless kiwi. (*Russ Kinne from Photo Researchers; Walter Dawn; New Zealand Embassy*)

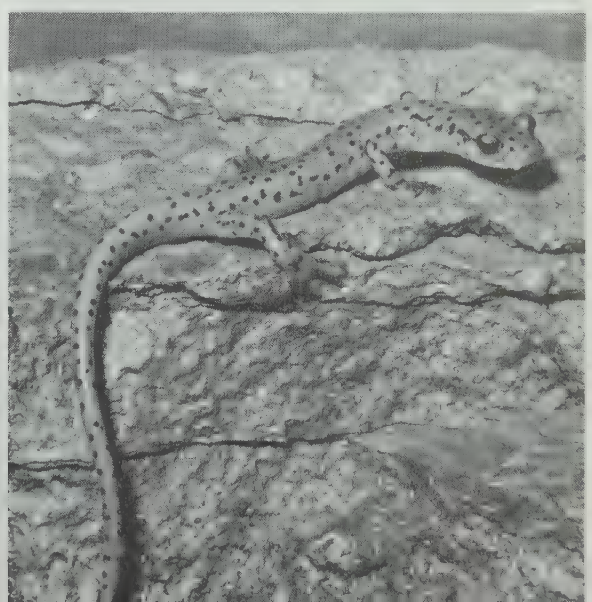


5–5. Name some characteristics common to all reptiles. Top, crocodile; bottom left, copperhead; bottom right, horned toad. (*Irwin from Monkmeyer; American Museum of Natural History; U.S. Forest Service*)

the alligators and crocodiles, many lizards, the turtles, and the snakes.

4. ***Amphibians*** (am-*fib*-ee-uns). Amphibians are cold-blooded vertebrates which some people confuse with the reptiles. Amphibians, however, have no external scales or plates. In early life they use gills to get oxygen from the water, but as they grow older some of them develop lungs. Amphibians in-

5–6. How do amphibians differ from reptiles? Left, tree frog; right, cave salamander (*Hugh Spencer; Harrison from Monkmeyer*)



clude such types as the frogs, toads, and salamanders.

5. ***Bony fish.*** This is a group of cold-blooded vertebrates adapted to life in the water. Their skeletons contain many bony parts. All bony fish have gills, although a few species develop lungs as well. Among them are such well-known types as the catfishes, basses, eels, flounders, herrings, mackerels, perches, pikes, salmon, and trout. Some of these fish live in fresh water, some in the sea, and some spend part of their lives in both fresh and salt water.

6. ***Sharks*** and ***rays.*** They are salt-water species, and they are often called "fish." They differ from the bony fish, however, because among other things, the skeletons of sharks and rays are largely composed of cartilage. Sharks and rays have gills, but no gill covers.

7. ***Lampreys*** (*lam*-prys). The lampreys and related types known as hags are fishlike animals, that have skeletons of cartilage and develop gills. They do not have true jaws or paired fins.

5–7. The sea horse is an interesting bony fish. (*Walter Dawn*)

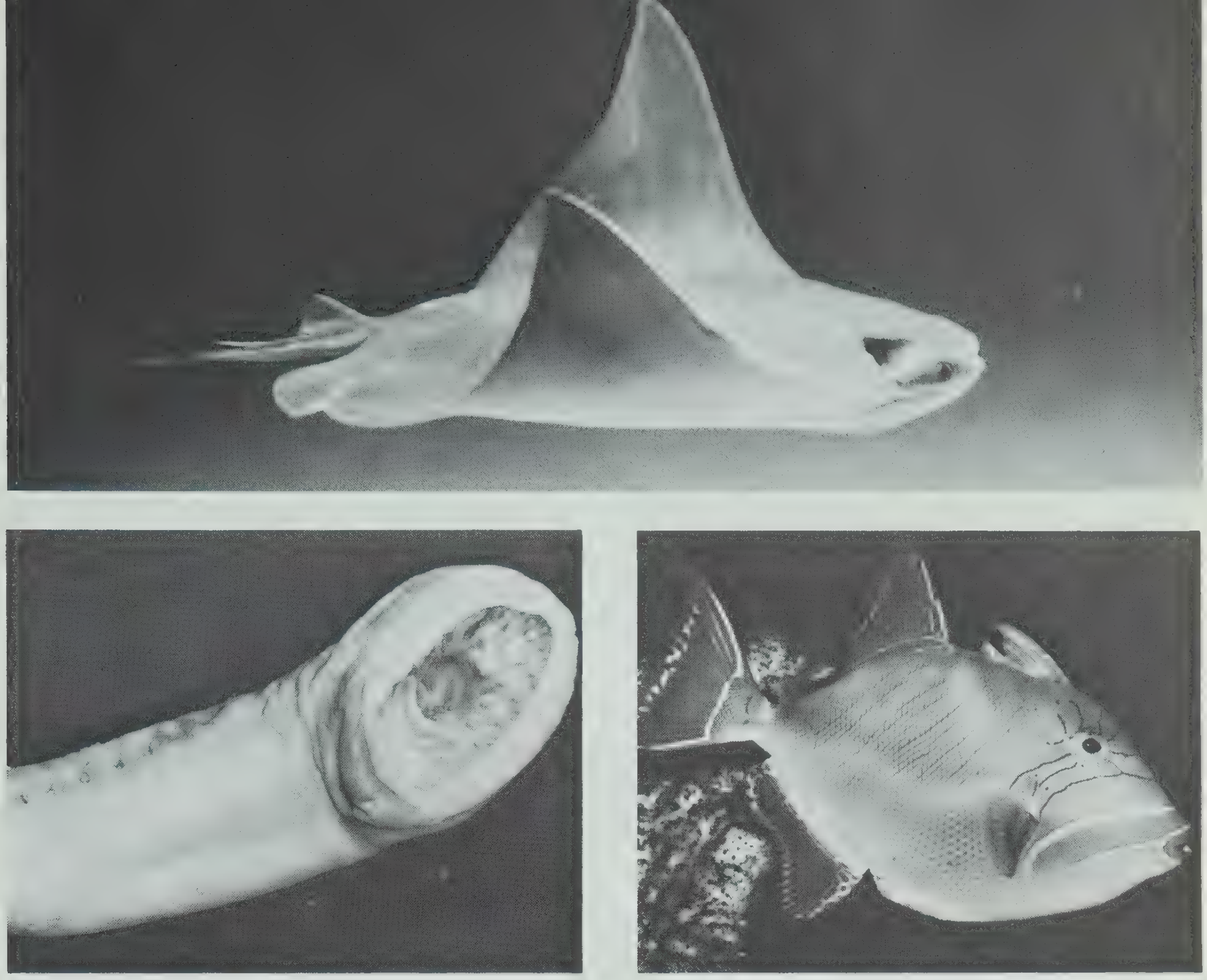
The arthropods (*ar*-thro-pods). The *arthropods* make up a phylum of invertebrates or animals *without* backbones. They have segmented bodies and jointed legs. There are far more species in the arthropod phylum than in any other. The following three classes of arthropods are of special importance:

1. ***Arachnids*** (uh-*rack*-nids), which includes the scorpions, spiders, and ticks. Many people confuse them with the insects, but you can always tell the difference if you remember that an insect has six legs. Arachnids generally have eight legs.

2. ***Insects.*** Some insects have wings, and others do not. This group includes such familiar types as dragonflies, bugs, beetles, moths, bees, ants, and many others. It is believed that there are over a million species of insects.

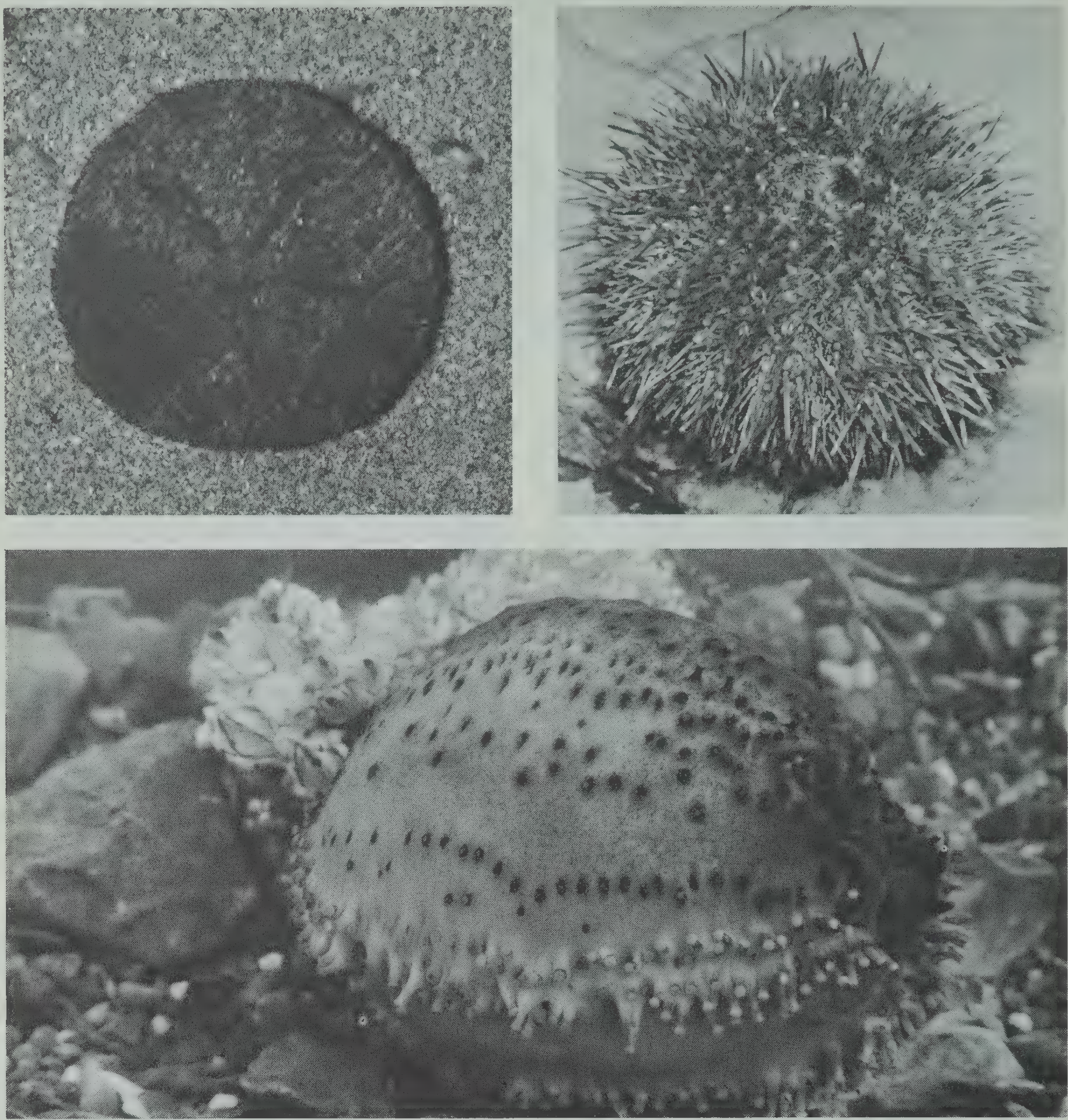
3. ***Crustaceans*** (krus-*tay*-shuns). Many crustaceans live in the water, but some are found in moist places on the land. In this group there are many types that you are probably familiar with, such as the crabs, crayfish, shrimps, and lobsters.

The echinoderms (*ee-ky*-noh-*derms*). Together with sand dollars, sea lilies, and sea cucumbers, the starfishes and sea urchins make up an interesting phylum of *echinoderms* whose members all live in the sea. You have probably seen starfishes and other members of this group. Their body walls contain hard lime plates, and many of the plates bear spines. Sea cucumbers, however, have only a few plates in their body walls, and these animals are often smoked, dried, and then used as food in some Oriental countries.



5–8. Three classes of fish. Top, ray; bottom left, lamprey; bottom right, bony fish (queen trigger fish). (*Russ Kinne from Photo Researchers; Karl Maslowski from National Audubon Society; Walter Dawn*)

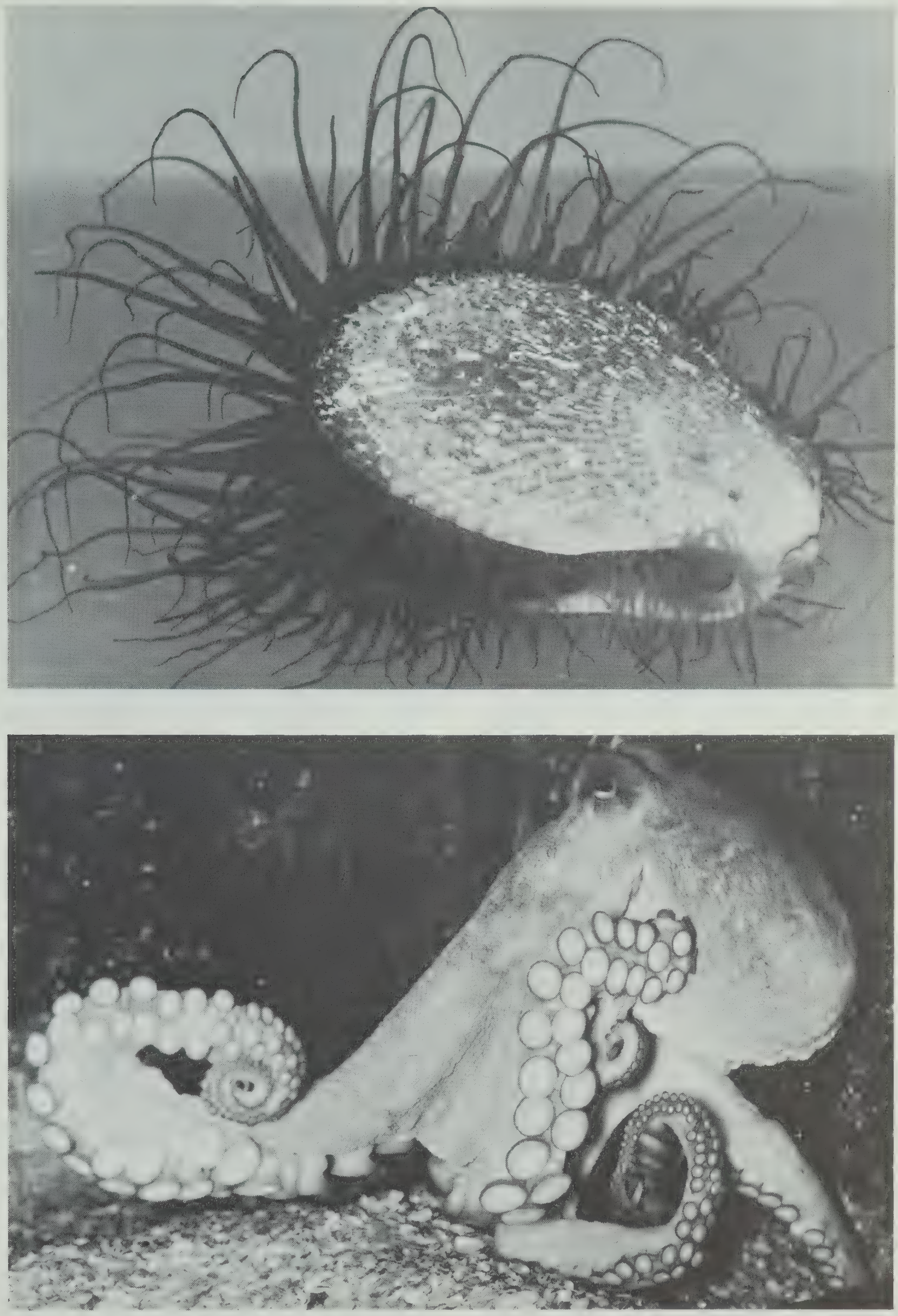
5–9. What classes of arthropods are represented below? (*Top left, Carew from Monkmeyer; top right, Kennedy from Monkmeyer; bottom, Ross E. Hutchins*)



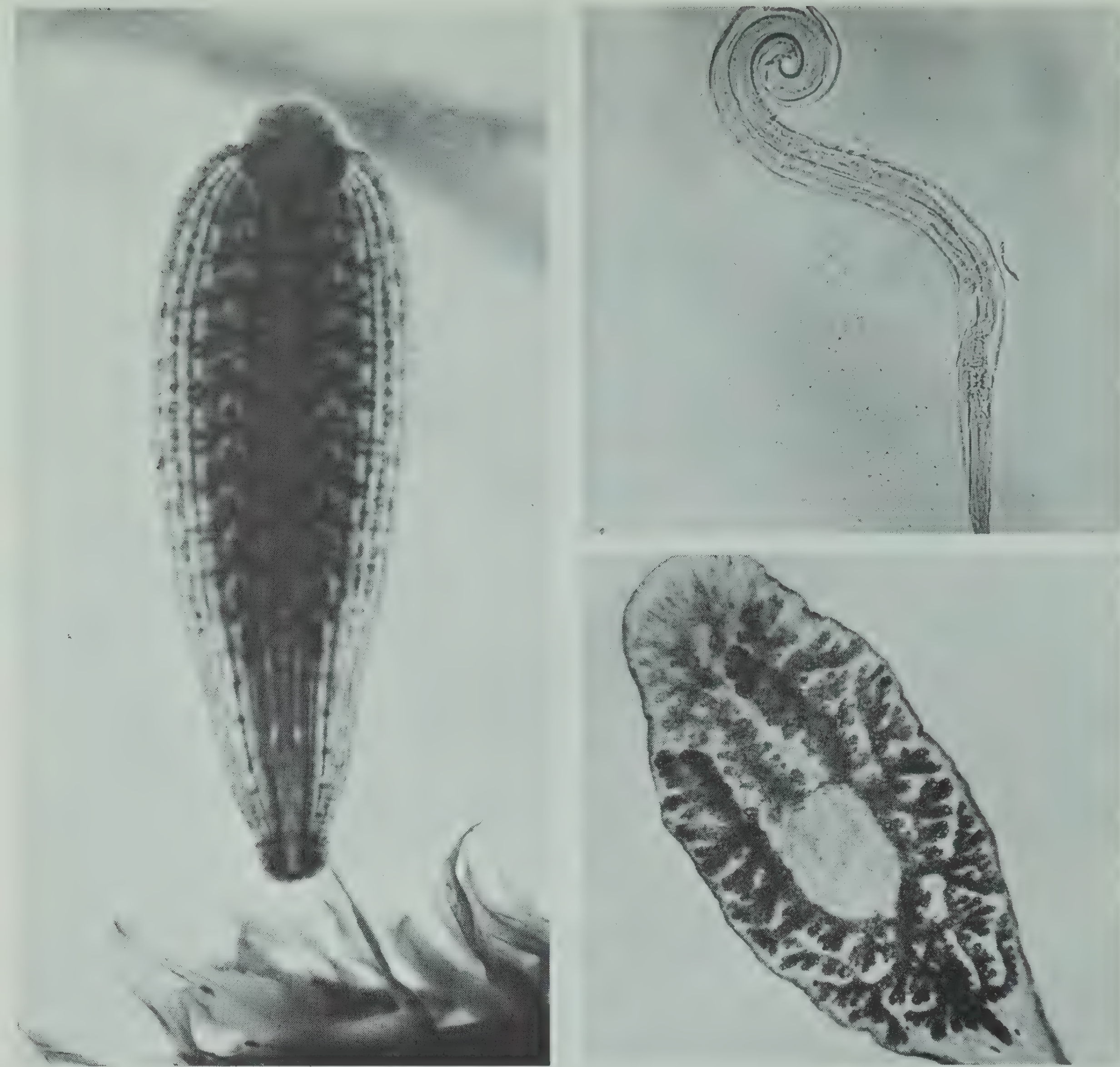
5–10. Diversity among echinoderms. Top left, sand dollar; top right, sea urchin; bottom, sea cucumber. (*H. W. Kitchen from National Audubon Society; Walter Dawn; Russ Kinne from Photo Researchers*)

The mollusks (*mollusks*). The *mollusk* phylum includes members living on land, in fresh water, and in the sea. Examples from this phylum are snails, clams, oysters, octopuses, and squid. As you know, snails, clams, and oysters have soft bodies with hard outer shells. Octopuses and squid have soft bodies with rodlike internal supports. Many members of this group are used as food for humans, including octopuses. Various species of clams and oysters, found in both fresh and salt water, are sources of pearls, and their shells are often used to make pearl buttons and jewelry.

The segmented worms. This phylum includes the *segmented worms* that are found on land, in the soil, in fresh water, and in the sea. They are readily distinguished from other types



5–11. The clam and octopus shown in these pictures appear quite different, but both of them are mollusks. (*Marineland of Florida*)



5–12. Three types of worms; left, a leech; top right, a pinworm; and bottom right, a planarian. Which worms would you classify as segmented, round, or flat? (*Left, Hugh Spencer, top and bottom right, Walter Dawn*)

of worms because their bodies are divided into sections, and because they have well-developed body cavities. The familiar earthworms belong to this group. Perhaps you have also seen leeches, some of which are bloodsuckers. In addition, there are many other types of segmented worms found in the sea and freshwater ponds and streams that are less well known.

The roundworms. The members of this phylum have elongated, cylindrical bodies, with a digestive canal extending from a mouth opening at one end to an anal opening at the other. Their bodies are not divided into segments. Many roundworms live within the bodies of plants and animals, and some of them are the cause of serious diseases. Other species are free-living types, some of them living on the land or in the soil, and some of them living in the water. The roundworms include the hookworms and eel worms.

The flatworms. The *flatworms* make up the third phylum of wormlike animals. Some of them live in the bodies of larger animals, but others are free-living species. Various flatworms exist in fresh water, salt water, and on land. They generally are flattened in form, and they do not have digestive canals with anal openings. In fact, some flatworms, such as the tapeworms, have no digestive system at all. Food is absorbed through their body surfaces. Tapeworms are the best known members of this phylum. The group also includes animals called flukes.

The coelenterates (soh-*len*-terr-ates). This phylum includes the *corals* which are found in the sea, although some of their relatives dwell in fresh water. Among the latter is the hydra that you studied in Chapter 4. The members of this group have simple digestive cavities with only a mouth opening to the outside. They develop stinging cells which are sometimes used in capturing food and warding off enemies. Some corals develop extensive colonial growths, and coral reefs are well known in the warmer seas. Sea anemones and jellyfish are also members of this phylum.

5–13. The sea anemone, an example of a coelenterate. (*Russ Kinne from Photo Researchers*)

5–14. Two types of living sponges. (*Walter Dawn*)

The porifera. This phylum includes the *sponges* that live largely in the sea, although some species inhabit fresh waters. Early students of these animals believed them to be plants, because as adults, they live attached to some object in the water. Like corals, sponges secrete skeletons, and some types develop extensive colonial growths. The skeletons of some sponges are soft when wet, and can be cleaned and trimmed to produce bath sponges.

THE PLANT PHYLA

In describing the plant groups, we shall follow the same procedure as in the case of the animals, and begin with the more modern and complex types.

The vascular plants. This phylum includes the so-called *higher plants.* They have special vascular tissues through which liquids pass from one

5–15. Diversity among seed plants. Moccasin flower, left; top right, live oaks; bottom right, pea plants. (*U.S. Forest Service; Walter Dawn; Grant Heilman*)

5–16. The cycad (left) and the fir tree (right) are both cone bearers. Can you identify the cones in the picture on the right? (*Walter Dawn; U.S. Forest Service*)

5–17. Two types of ferns; a cinnamon fern (left); a tree fern (right). (*American Museum of Natural History; Emmy Haas from Monkmeyer*)

part of a plant to another. Among them are the many common types of land plants which we see every day. Five special groups of these vascular plants will be mentioned here, as follows:

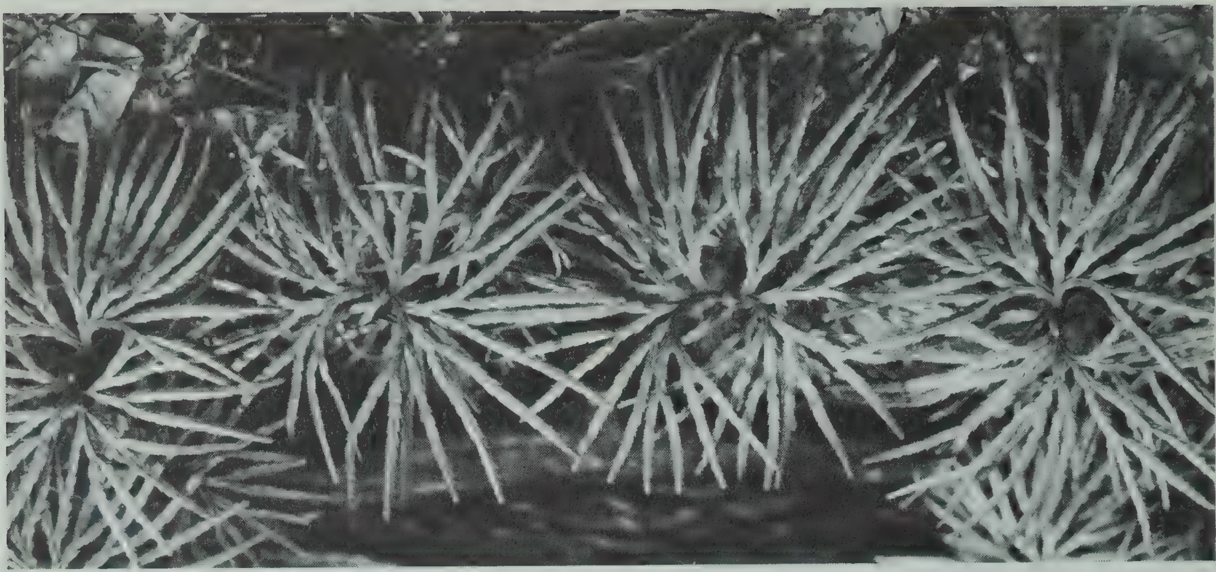
1. A very large group of ***seed plants*** which include the "flowering plants." Some other plants, however, also develop certain flowerlike structures. The plants of this group are clearly marked by their seeds, which are enclosed in seed cases. Included are various trees such as the birches, oaks, hickories, walnuts, maples, and elms. Others are such well-known plants as wheat, corn, grasses, lilies, poppies, morning glories, roses, beans, peas, and sunflowers, to mention only a few.

2. A much smaller group of seed plants which do not develop seed cases. These plants are ***cone-bearers,*** and include such trees as the pines, hemlocks, spruces, firs, and redwoods. Many of them are important forest trees.

3. A fairly large group of ***ferns.*** These plants, as well as those in the groups that follow, develop no seeds. Ferns grow as underground stems, from which leaves that are called fronds arise. They are likely to be most common on fairly moist soils.

4. A group of ***horsetails*** which includes only about two dozen modern species.

5–18. An example of spore cases of a horsetail. (*Hugh Spencer*)



5–19. This club moss has a very unusual structure. (*Hugh Spencer*)

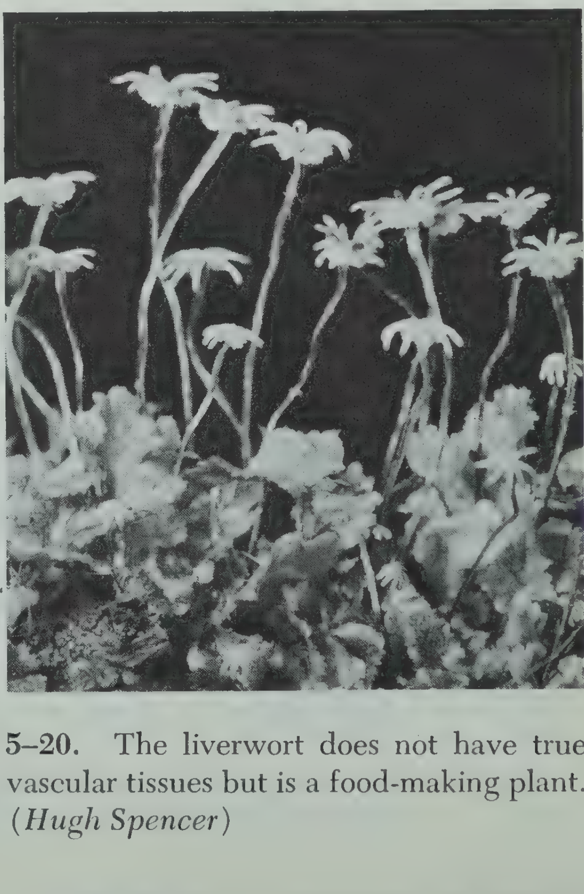
These plants also develop underground stems, and upright stems that rise above the surface. The upright stems are jointed, and bear small, scalelike leaves. In past geological eras horsetails were far more common, and some of them grew to be 90 feet tall.

5. A group of ***club mosses*** which have stems near the surface of the ground, and upright stems that usually bear spiral clusters of small leaves. Modern members of this group are small, but some extinct types were the size of large forest trees. Carefully study the club moss shown in Fig. 5–19.

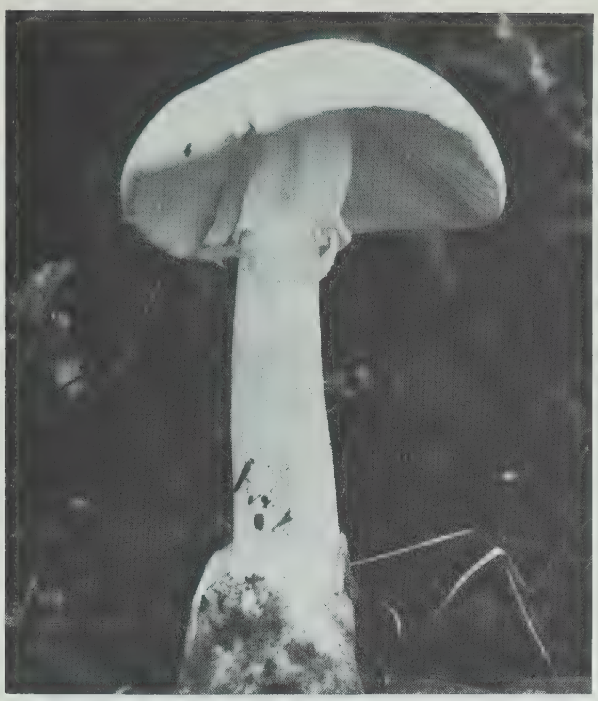
The mosses and liverworts make up a phylum of rather small plants that generally grow close to the soil in moist places on the land or at the water's edge. Mosses and liverworts do not have true vascular tissues, but they contain chlorophyll and are food producers. You have studied a moss plant in Chapter 4.

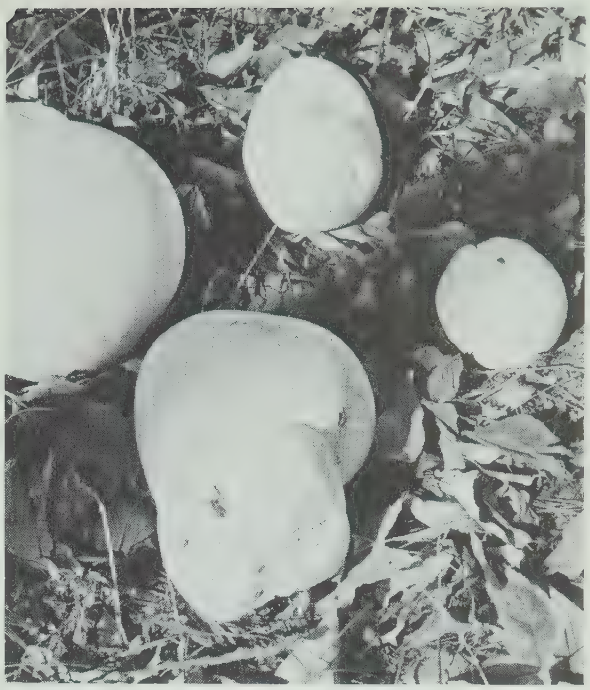
The higher fungi. This is a phylum of true fungi. Its members have no chlorophyll, and are unable to make foods. They obtain nourishment by feeding upon other organisms. The group is quite large, and includes such types as the mildews, molds, mushrooms, rust fungi, smut fungi, and yeasts. Some of the mushrooms are fairly large, but some other members of the group are very small.

The algae. Several phyla of simple plants are known as *algae.* Some of them are single-celled. Others grow as filaments of cells, and still others de-



5–20. The liverwort does not have true vascular tissues but is a food-making plant. (*Hugh Spencer*)

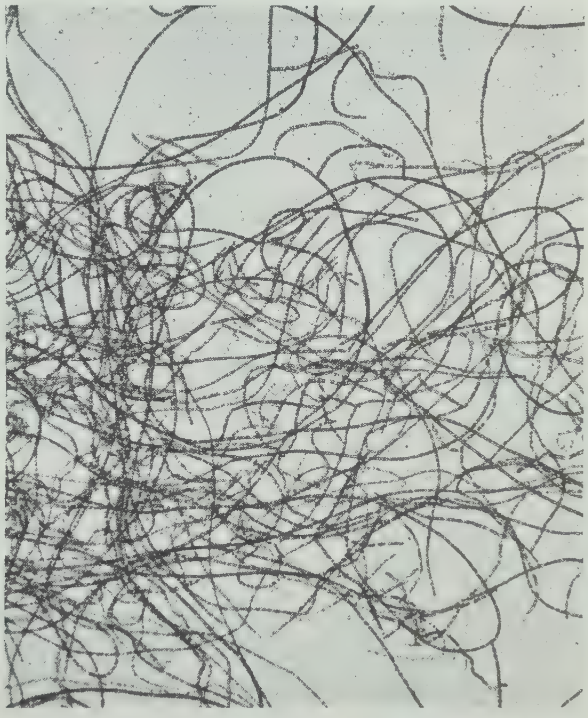




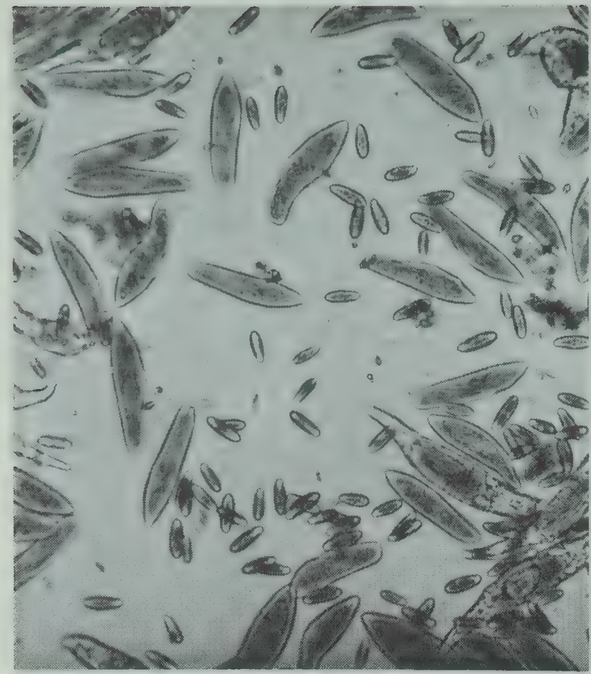
5–21. The mushroom on the left is called the "death cup" and is extremely poisonous. The puffballs on the right are edible, as are some mushrooms. (*Hugh Spencer; Karl Maslowski from Photo Researchers*)

velop massive growths, as in the case of the rockweeds and the kelps. Red algae, brown algae, yellow-green algae, and green algae are members of these plant groups. Most of them live in water, but some species are found on land in damp places. Regardless of their color, algae contain chlorophyll. In addition, some of them have other pigments which mask their green color.

5–22. An example of rust fungus which has infected apple leaves. (*Hugh Spencer*)



5–23. Freshwater thread algae. (*Carl Struwe from Monkmeyer*)



5–24. Mixed protist culture. Can you identify any of the organisms? (*Hugh Spencer*)

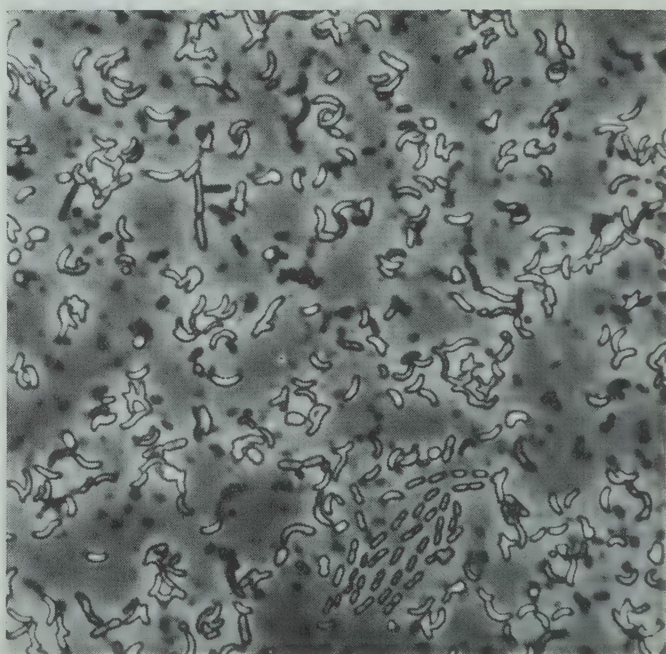
THE PROTISTS

After studying this chapter you may feel that the system used in naming and grouping organisms is a very useful one. And it is indeed, but it is not without problems. Again and again, since the time of Linnaeus, the system has been changed somewhat, and it will no doubt undergo more changes in the future. One reason for making changes is that as biologists learn more and more about living things, they discover organisms that do not fit neatly into any of the established groups. New classes, orders, or other groups have been set up to take care of such cases.

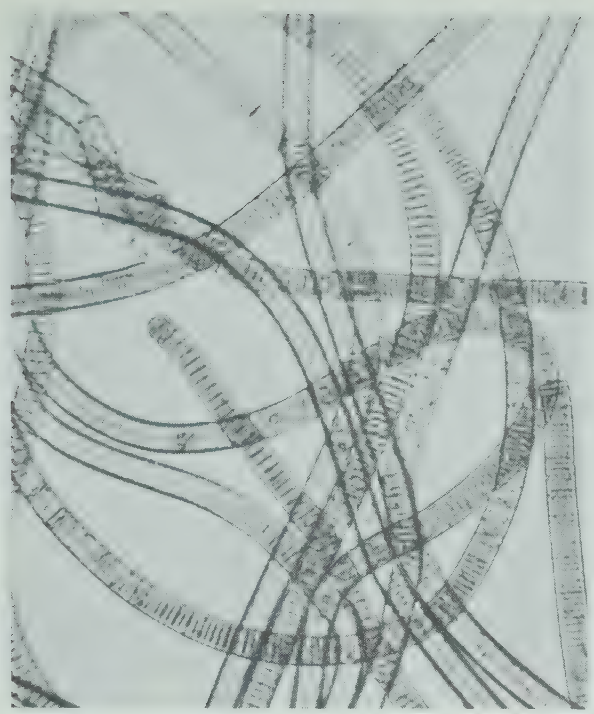
Biologists also discover *borderline* types that are difficult to deal with. For example, green plants are usually organisms that make their own food, and live out their lives in one place. Animals are organisms that cannot make their own foods, but many of them can move about. But some organisms are now known that can move about freely, make their own food when in the light, and seek other sources of food when in the dark. Should such organisms be assigned to the Plant Kingdom or to the Animal Kingdom? There are some borderline types that do not even have well organized cells.

In order to classify organisms that do not fit well into either the plant or the animal pattern, some biologists have suggested the creation of a new kingdom. This new kingdom, the ***protists*** (*proh*-tists), is rapidly becoming accepted as the third kingdom. It includes various small borderline types. Among them are the following:

The bacteria make up a phylum of single-celled organisms, that are usually without chlorophyll, and have no organized nuclei. Some *bacteria* are very useful types, but the group also includes species that are the cause of dangerous diseases which affect plants and animals, including man. Typhoid fever, diphtheria, and tuberculosis are examples of these diseases.



5–25. Mixed bacteria (spirilli, cocci, and bacilli). (*Walter Dawn*)

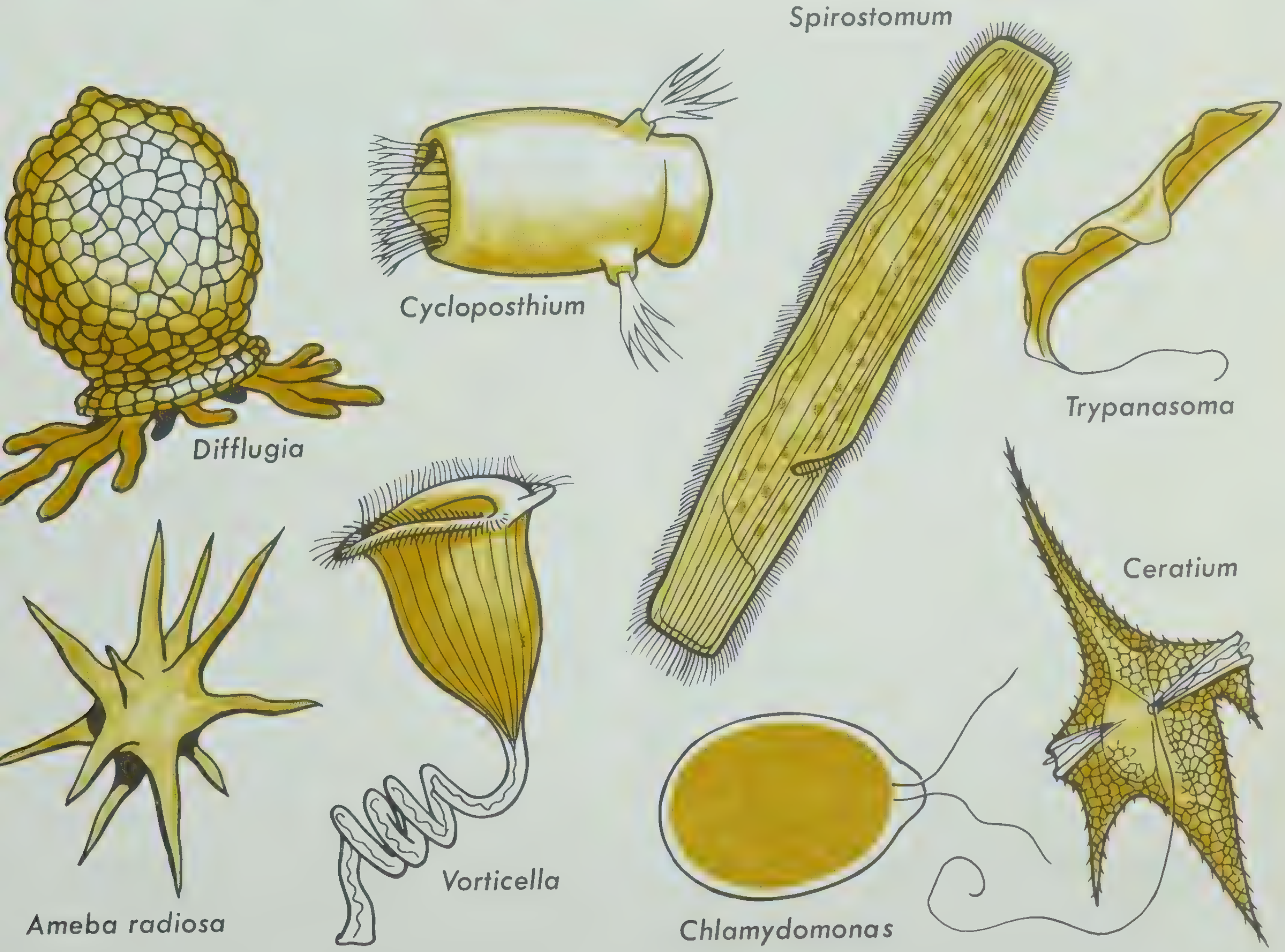


5–26. Blue-green algae. (*Hugh Spencer*)

The blue-green algae. This is a group of very simple algae. They are single-celled types, and like the bacteria, they do not have organized nuclei.

The sporozoans. The sporozoans are single-celled organisms that are sometimes placed in the phylum ***Protozoa*** (proh-toh-*zoh*-uh). Sporozoans, however, are very small, and have no means of moving from place to place under their own power.

Other protozoans. In this category are certain organisms that are quite small, and simple in structure. Until recently they were classified as the simplest animals. Many of them are single-celled species, and others live as colonies of cells. You find them on land,



5–27. Diversity among protozoans.

5–28. Slime molds are one of nature's puzzles. They change from "animal" to "vegetable" and back again. (*Harold Green from APF*)

in the soil, and in both fresh and salt water. Some species even live within the bodies of other plants and animals.

The slime molds. This is a group of interesting organisms that have been classified with the fungi. Their spore stage is plantlike and resembles the higher fungi. Slime molds also show animal-like movement. They inhabit the forest floor and can be found growing on damp, decaying leaves.

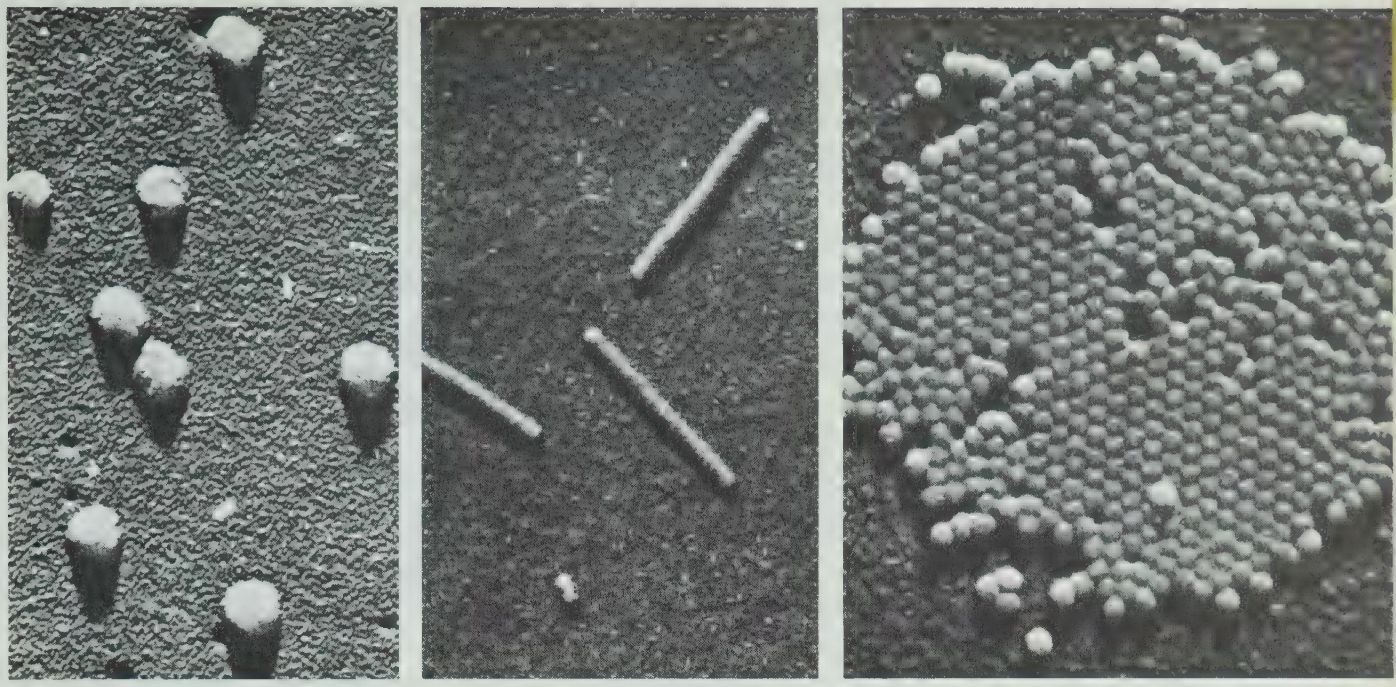
THE VIRUSES

We come now to a group of substances that have some of the characteristics of living things. They might also be regarded as very active *nonliving* chemicals. These are the ***viruses*** (*vy*-ruses), which are the cause of various diseases in both plants and animals.

Viruses are made up of exceedingly small particles. You can see bacteria when you use the highest power of an ordinary microscope, but you would not be able to see viral particles. In order to see viral particles you need the much greater power of an electron microscope. Then they become visible, usually as ball-like or rodlike forms. You can get some idea of their tiny nature when you consider that you would need about 25 million of these particles to make an object as big as a pin head.

Studies have shown that when viral particles get into the right kind of living cell they can reproduce themselves. It also appears that their heredity can change. In these ways they are behaving like living things. But, when you remove them from the living cell that shelters them, they become inactive and appear to be nonliving. Studies have also shown or indicated that each viral particle is made up of a minute portion of nucleic acid and several protein molecules.

There is still a good deal of mystery about the viruses. But their importance



5–29. Diversity among viruses. Left, influenza; center, tobacco mosaic; right, polio. (*Courtesy of the Virus Laboratory, University of California, Berkeley*)

is obvious, because they are the cause of such human afflictions as common colds, influenzas, polio, mumps, smallpox, and yellow fever, not to mention many serious diseases of the plants and animals.

VASCULAR TISSUES

In reading about plants you learned that some of them have vascular tissues. These tissues conduct water containing dissolved substances from the roots to the stems, and then to the leaves. Liquids containing foods also move from the leaves to the stems and roots.

In the higher plants these vascular tissues form a series of *ducts*. You can see how they serve to carry water up through a plant stem by performing the following demonstration.

THE RISE OF LIQUID IN A CELERY STALK Put about an inch of red or blue ink or a laboratory stain in a glass cylinder as shown in Fig. 5–30. Insert the cut end of a celery stalk in the liquid, and let it remain there for at least 30 minutes. This allows time for the colored liquid to move up ducts in the stem.

Now remove the celery stalk and cut off thin slices, starting at the lower end, and using a sharp knife or razor blade. You can see the location of the ducts because the cells that form their walls are now stained. To get a better idea of what has happened, cut a slice as thin as you can, wash it in water, put it on a blank slide, and examine it with the low power of a microscope.

Keep on slicing your stem, and see how far the colored liquid moved up the ducts in the time you allowed. Observe the location and arrangement of the ducts.

ANALYSIS After you have completed this observation, prepare answers to the

following questions in your notebook:

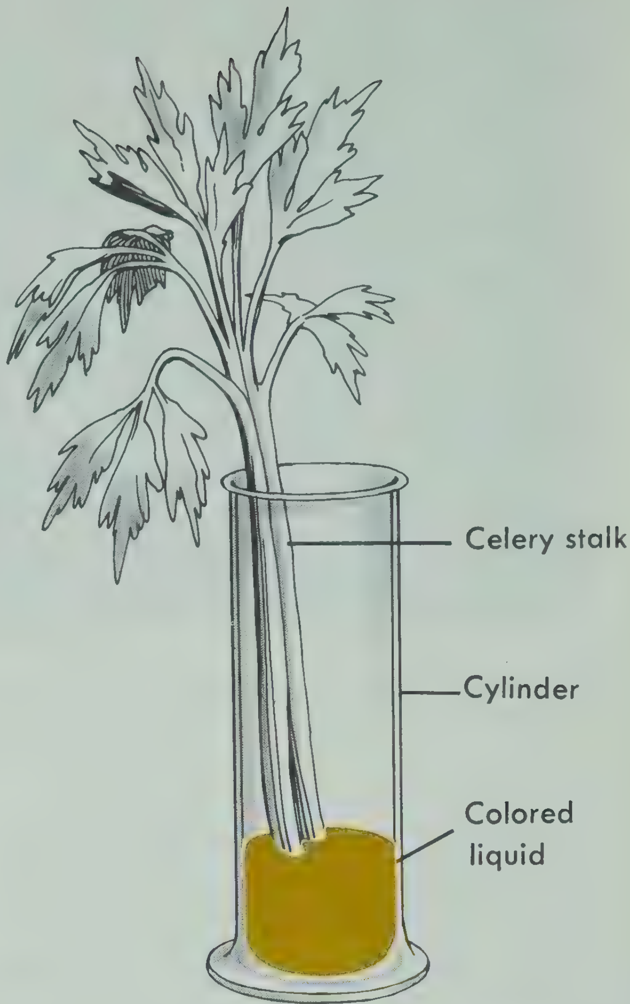
1. Where were the ducts located in the celery stalk? Do you suppose that they have the same location in a corn stem? How could you find out?
2. Do the cells of the ducts differ in appearance from other cells that surround them?

ANOTHER EXPERIMENT WITH CELERY STALKS Do you think that the vascular system of a celery plant functions well under all sorts of conditions? Or do you think that such things as light, temperature, or soil chemicals may have some effect on how it works? For example, would the vascular system be affected if the plant was placed in salt or sugar solution instead of water alone?

We can use the time that it takes for ink to reach the top of a celery stalk as a rough measure of how the vascular system is functioning.

Cut several three-inch pieces from fresh celery stalks. Place one piece in each of several glass containers. Add one of the following to each container:

1. A half-inch of water
2. A half-inch of 5 percent salt solution
3. A half-inch of 10 percent salt solution
4. A half-inch of 5 percent sugar solution
5. A half-inch of 10 percent sugar solution



5–30. The colored liquid will rise through ducts in the celery stalk.

Stain each of the liquids in the containers by adding an equal amount of red or black ink.

Now observe in each case how long it takes for the ink color to appear at the top of the celery stalk. Make a copy of the following data sheet in your notebook, and record your findings:

Liquid	Time for stain to appear
Water	
5 percent salt solution	
10 percent salt solution	
5 percent sugar solution	
10 percent sugar solution	

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways did the salt solution seem to affect the functioning of the vascular system? The sugar solution?
2. Knowing that green plants make sugar and then use it as a food or energy source, do you think that plants could be fed sugar by putting sugar in the soil? Explain.
3. Salt is sometimes used as a weed killer. What appears to be the basis for this practice? What problems might this practice create if other plants are growing in the same area?

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. genus	Includes protozoans.
2. protists	Have characteristics of living and nonliving things.
3. species	One kind of living thing.
4. variation	First part of a scientific name.
5. vertebrates	Differences among members of a group.
6. viruses	Animals with backbones.

B

1. amphibians	Have soft bodies, often with a hard covering like a clam.
2. arthropods	
3. birds	Have skin with hair.
4. mammals	Skin covered with dry scales.
5. mollusks	Skin with feathers.
6. reptiles	Cold-blooded vertebrates without scales or plates.
	Invertebrates with jointed legs.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Nonscientists are generally agreed on what names to use for living things.
2. In the scientific name for the cat, *Felis domestica, Felis* is the species name and *domestica* is the genus name.
3. The Latin names used for organisms usually are descriptive of the organisms.
4. The fact that the peach tree and the cherry tree are placed in the same genus indicates that scientists feel that these trees are closely related.
5. More variation is expected among the members of an order than among the members of a phylum.
6. Related phyla make up a kingdom.
7. Vertebrates are considered to be more complex than invertebrates.
8. Birds are cold-blooded animals.
9. Reptiles have moist, slimy skins.
10. Catfish, bass, and trout are placed in the group called "cartilaginous fish."
11. Lampreys do not have true jaws or paired fins.
12. Spiders, insects, and crustaceans are grouped in the same phylum.
13. Occasionally, members of the starfish group are found living in fresh water.
14. Earthworms and leeches have bodies that are divided into sections or segments.
15. Roundworms and flatworms are similar in that they have only one opening to their digestive canals.
16. Coral animals and their relatives generally develop stinging cells.
17. Sponges are found only in the sea.
18. Vascular plants are believed to be less complex than nonvascular plants.
19. Mosses have well-developed vascular tissues.
20. Algae commonly cause decay.
21. Brown algae cannot produce their own food because they lack chlorophyll.
22. Viruses cause diseases in plants as well as in animals.
23. Most viral particles are slightly larger than bacterial cells.
24. Influenza, mumps, and common colds are virus diseases.

DISCUSSION QUESTIONS

1. Why were early men interested in plants and animals?
2. Why are scientific names important?
3. In what ways are scientific names thought to reflect relationships among organisms?
4. In what ways do humans vary? How may identical twins vary?

5. Although a "grasshopper does not look much like a polar bear," in what ways are they similar?
6. In what ways would plants be expected to vary?
7. What are the advantages of being warm-blooded? Cold-blooded? What are the disadvantages of each?
8. Why are amphibians sometimes confused with reptiles? How can they be distinguished?
9. In what ways is the term "fish" confusing? The term "worm"?
10. How can a spider and an insect be distinguished?
11. Arthropods are sometimes called the dominant animals on earth today. What argument can be made for this point of view? Against it?
12. Why do you think the insects are so numerous?
13. In what ways is the seed of a flowering plant different from the seed of a cone-bearing plant?
14. How is water obtained by cells of nonvascular plants?
15. What arguments can be made in favor of destroying all bacteria?
16. In what ways are viruses like living things? Like nonliving things?
17. Do you think there is a necessity for a third kingdom? Explain.
18. Some groups of animals are found only in salt water. Other groups are rarely found in salt water. How would you explain this observation?

THINGS TO DO

1. Using a large piece of cardboard or construction paper, prepare a chart to illustrate the major groups within the system used to classify living things. Select a single organism, like man for example, as the theme of the chart. Across the top of the chart arrange pictures to illustrate members of each phylum in the kingdom in which man is grouped. In a second line arrange pictures to illustrate members of each class in the phylum in which man is grouped. Prepare a third line of pictures to illustrate members of each order of the class in which man is grouped, etc. Use reference books to find out what you need to know about the members of each group.
2. Make a study of common names used for various organisms by the people in your region of the country. Select preserved or living specimens of a few organisms. Show them to as many people as possible, and ask each person what name or names he knows for each type of organism. Report your findings to the class.
3. Visit a market and make a list of different kinds of plants and animal materials that are offered as foods. On your list indicate the phylum in which each kind of food is grouped. See how many different phylum representatives you can find. Make a second list of phylum representatives that are used for purposes other than as foods.
4. Bring to class a specimen of a plant or animal common in your region

of the country. Label it with its common name or names. Using reference books see if you can find out its scientific name and the names of the other groups—phylum, class, order, etc., to which it is assigned.

5. Make a collection of specimens or pictures to illustrate representatives of as many animal phyla as possible. Make a second collection to illustrate plant phyla. Ask your teacher what kinds of specimens you should attempt to collect, and where they may be obtained. Display your collections for the class.
6. Visit a library and notice how the various kinds of books are arranged or grouped. Write a short report to explain how the systems used in grouping books and living things are similar.

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BLOCK I

Laboratory Investigations

This section of your book deals with biological materials, and the ways they are used in carrying out demonstrations and experiments. It is divided into three parts, as follows:

Part I is concerned with books, instruments, and general procedures in studying plants and animals.

Part II presents a number of demonstrations and experiments that relate to the materials discussed in Block I.

Part III provides instructions for the study of a pond community. Similar instructions for the study of a land community will be found in *Laboratory Investigations* for Block II.

PART I: BOOKS AND INSTRUMENTS

REFERENCE BOOKS AND GUIDES

In the *Reading Further* sections of the first five chapters are the titles of a number of reference books that are useful in studying the materials of Block I. No doubt there are many other useful books, including an encyclopedia, in your school library. In addition to your textbook, you will find various sources that can be consulted if you want to learn more about a particular subject. It is always best to consult many references and to take down brief notes from each source.

Suppose you want to look up the subject of *roundworms.* A good way to begin is to look in the indexes of your reference books. In the references you may find a number of statements about roundworms.

Or suppose you are planning an experiment. Probably you wish to find answers for some question. In such a case, one of the first things a scientist does is to try to find out what is already known about the question and what experiments have been done. He goes to various books and papers in an attempt to find out. Often the result is very helpful in planning his own experiment.

THE USE OF KEYS

The keys listed on page 141 are also reference books. But they are used largely to identify plants and animals that you do not recognize. Generally, it is not important to find the name of the particular species. But you may want to know whether some small pond organism is a crustacean, or an insect. Such questions are likely to arise when you study a pond community.

HOW TO USE A SIMPLE KEY To get an idea of how a simple key works, do the following exercise. As things to identify, use a sheet of notebook paper, a pen containing blue ink, a paper clip, an envelope, a lead pencil, a 3 × 5 card, and a colored wax crayon.

To find the names of these things, use the key shown below. Start with lines *1A* and *1B*. Decide whether *1A* or *1B* fits the item you are trying to identify. Now you will either move to *Group 2* or *Group 4*. Here you will find the name of your item, or be referred to another *Group*. Check all of your items in this fashion, and you will soon be ready to use simple keys.

1A	Made of paper	see 2
1B	Not made of paper	see 4
2A	Folded and glued to form a container	envelope
2B	Not folded and glued	see 3
3A	8½ inches wide; 11 inches long	notebook paper
3B	3 inches wide; 5 inches long	card
4A	Makes a colored mark on paper	see 5
4B	Does not make a colored mark on paper	paper clip
5A	Made of wax	crayon
5B	Not made of wax	see 6
6A	Makes a black mark on paper	pencil
6B	Makes a blue mark on paper	pen

BIOLOGICAL EQUIPMENT

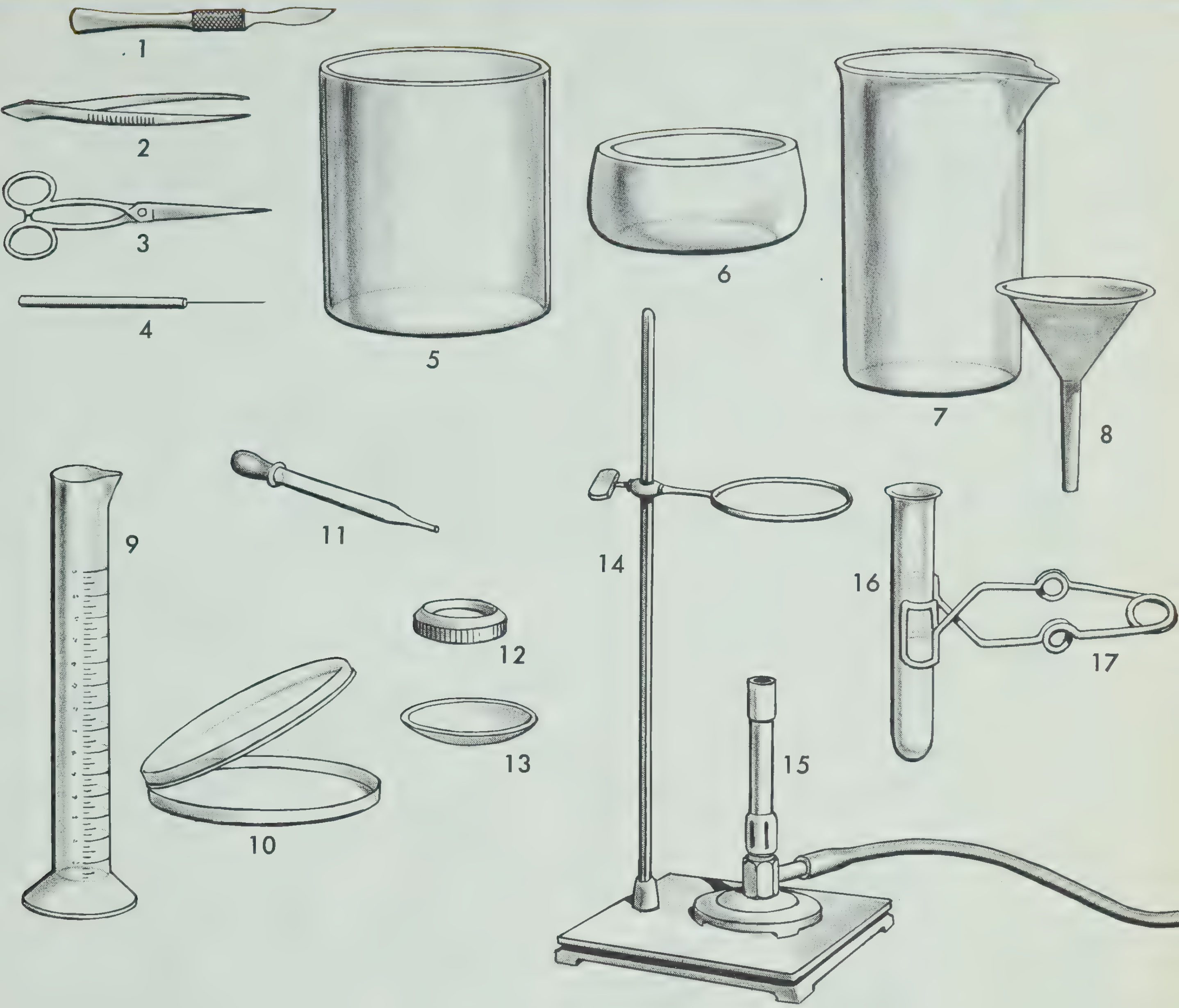
INSTRUMENTS AND GLASSWARE Fig. L–1 shows a number of instruments and other items that are used in biological studies. You probably can guess that the scalpel, forceps, scissors, and needle are used to dissect various parts of plants and animals. Be careful in using these sharp or pointed instruments. Keep them away from your eyes.

The battery jar and the culture bowl will both serve as containers for pond cultures. Battery jars come in various sizes. A large one can even be used to set up an aquarium.

Beakers also come in various sizes, and are useful for holding and pouring liquids. Funnels are used to filter liquids and to pour liquids from one container to another container. A graduate is used to measure precise amounts of liquid. Be especially careful how you pour any acid. If you get acid on your skin, wash it off as quickly as possible.

In petri dishes you prepare surfaces on which bacteria and fungi will grow. These dishes have glass covers to keep out dust and prevent rapid drying.

When you want to look at some small organisms from a pond culture, you first draw them up in a pipette. Then you may wish to put them in a watch glass if they are large enough to



L–1. Laboratory glassware and instruments: (1) scalpel, (2) forceps, (3) scissors, (4) dissecting needle, (5) battery jar, (6) culture bowl, (7) beaker, (8) funnel, (9) graduate, (10) petri dish, (11) pipette, (12) watch glass, (13) crystal watch glass, (14) ring stand, (15) Bunsen burner, (16) test tube, (17) test tube holder.

be seen without the use of a microscope.

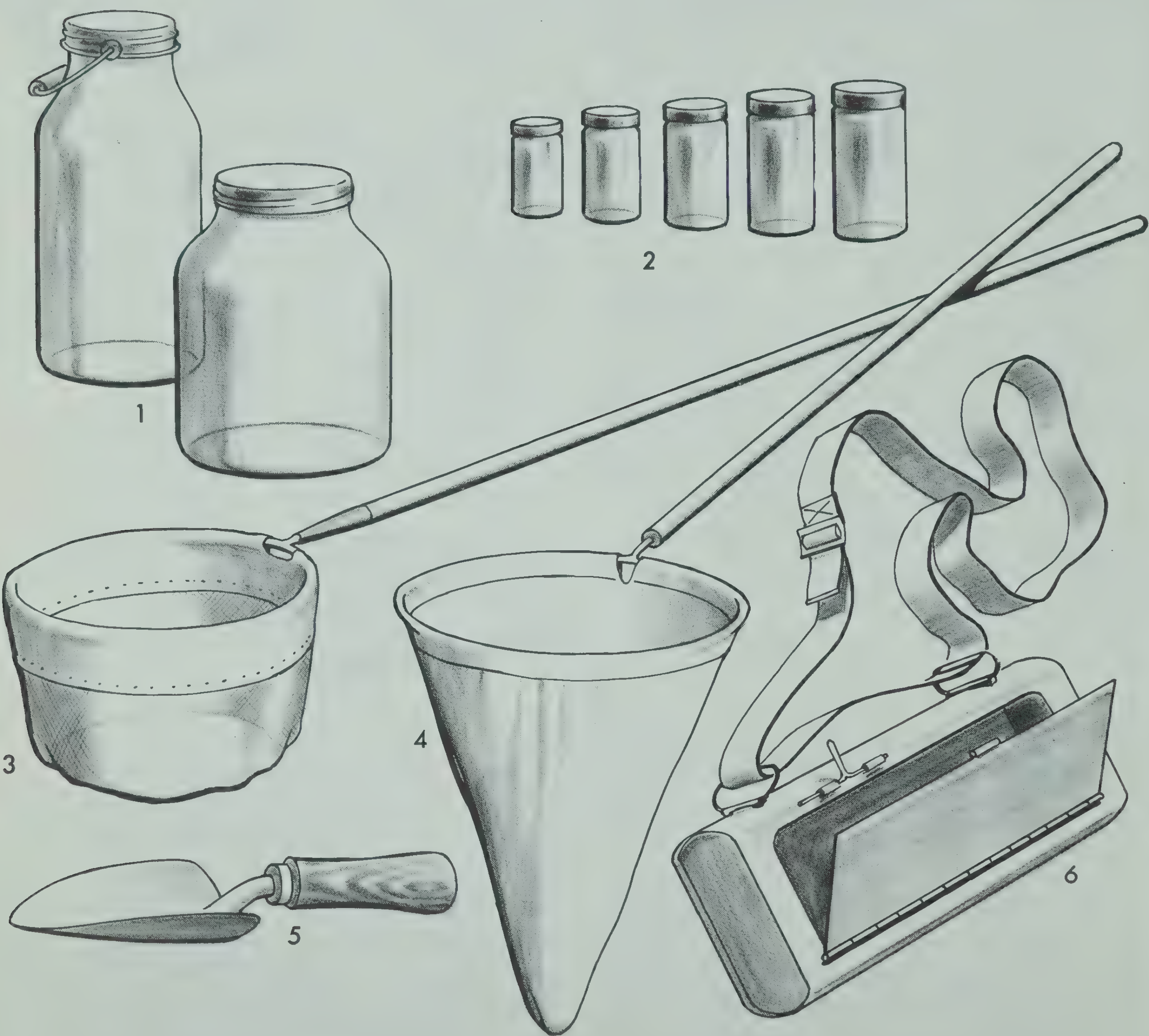
A Bunsen burner provides a flame that can be used to heat objects. Thus, you can place a Bunsen burner on the base of a ring stand, and heat a pan of water that rests upon the ring support.

You can also hold a test tube containing water with a test-tube holder, and keeping it well away from your face (in case boiling water is forced out of the tube), heat the lower portion of the test tube slowly in the Bunsen flame. But remember to have the out-

side of the test tube dry when you do this; otherwise the test tube may break. Always find out what you are heating and never attempt to heat anything that burns or explodes, such as alcohol, in a test tube. When you heat alcohol, use a water bath, as described on page 122.

COLLECTING AND CULTURING

MATERIALS FOR FIELD COLLECTING Fig. L–2 shows a number of items that will prove useful in field studies. The widemouth jars are fine for collecting pond cultures and supplies of pond water.



L–2. Field apparatus: (1) widemouth jars, (2) collecting bottles, (3) pond net, (4) insect net, (5) trowel, (6) collecting can.

The smaller collecting bottles, which also are of the widemouth type, can be used to carry small specimens of various kinds.

You can use one of the collecting bottles as a killing bottle. Attach a wad of cotton to the inside of the bottle lid. Moisten the cotton with a teaspoonful of carbon tetrachloride. Keep the lid on the bottle except when you put a specimen in it. Avoid breathing the gas that forms within the bottle.

One of the nets in Fig. L–2 is a pond net. It can be used to scoop up algae, as well as any small animals that are mixed in with the plant materials. The other net is used on the land to capture flying insects.

The collecting can is good for carrying various plant materials. It will also serve as a temporary container for small land animals. The trowel is useful in digging up surface soil samples, and such small plants as the mosses. You may also find various small animals when you turn over the surface soil with your trowel.

COLLECTING A POND CULTURE One of the things you may do fairly early in your study of biology is to collect and study a pond culture. Your materials will come from the shallow water at the pond's edge. It is probably best to collect them in several widemouth jars.

Fig. L–3 shows a profile of a pond's shore line. *Location A* in this diagram represents higher plants. *Location B* represents floating pond scums. *Location C* is a layer of decaying plant and animal material that collects on the bottom of a pond. *Location D* is the open water, where the depth is from six inches to a foot.

Begin to collect one sample by scooping up a half jar of water from *Location D*. Now add some of the pond scums from *Location B*. You can scoop them up with a pond net if they are out of your reach. If any of the plants at *Location A* have leaves that are in the water, pick three or four of these leaves and put them in your jar. Some of the small pond animals often cling to leaves and stems that are under the water's surface.

Collect another sample by scooping up a half jar of water at *Location D*. But this time add some litter found at *Location C*. To get this litter you may need a pond net. The litter is likely to be full of small organisms that have either fallen to the bottom or have sought shaded areas.

Obtain two or three more jars of pond water from *Location D*. The water in your cultures will tend to evaporate, and it is best to replace the loss with water from a natural pond.

CULTURES IN THE LABORATORY When you return to the classroom, transfer your materials from the collecting jars to culture bowls, like those shown in Fig. L–1. You can stack these bowls one above the other, with an empty bowl on top, and thus prevent rapid loss of water by *evaporation*. Put some of the bowls in a fairly well lighted place, and others in a location where only indirect light reaches them. Green plants such as the algae will generally prosper if they have plenty of light. Some of the small animals, however, need to be shaded from direct rays of the sun. Add

L–3. Profile of a pond shoreline. (A) Higher plants growing in shallow water; (B) floating pond scums; (C) layer of decaying plant and animal materials that collects on the bottom; (D) open water where depth is from six inches to a foot.

pond water from day to day to maintain about the same level in each culture bowl.

Quart or half quart battery jars, like the one shown in Fig. L–1, will also serve as containers for these cultures. But in this case you need plates of glass or other material to cover the jars; a sheet of plastic will work well. Otherwise, water loss may be very rapid.

If you find that you have a number of protozoa, such as paramecia in your culture, you may want to provide a more favorable place for them to live. If so, one method is to proceed as follows:

1. Boil four grains of wheat in a pint of pond water for about 30 minutes. Allow the water to cool, and then pour it in a culture bowl. The four wheat grains, which have been softened by boiling, go into the culture bowl with the water.
2. Leave the culture bowl uncovered for several hours, and then stack an-

other bowl above it to reduce water loss. Have a supply of boiled pond water on hand, and add enough from time to time to keep the water level in the culture bowl fairly constant.

3. After three or four days you will find a film of material on the water surface in your culture bowl. This film is made up of decay bacteria. They got into the water from the air when you left the culture bowl uncovered. These bacteria are excellent food for various types of protozoa, so you now have a good medium in which protozoa may live.

4. Locate a pond culture which contains a number of protozoa. To do this, you have to examine samples of the culture with the aid of a microscope. Now carefully draw a pipette full of water containing protozoa, and transfer it to your culture bowl.

5. Cover your culture bowl, put it where the light is indirect, and wait for several days. If all goes well, the protozoa will feed upon the bacteria, grow, divide, and become numerous.

PRESERVING SPECIMENS

Various small animals and samples of plant materials can be preserved for use at later times, or kept on hand as exhibit materials. We are talking about worms, small crustaceans and mollusks, insects, and pieces of plant stems or roots. The widemouth collecting bottles, shown in Fig. L–2, are good for the storage of such materials.

PRESERVING IN ALCOHOL Preserving in alcohol is a simple and direct method, although alcohol does cause most tissues to shrink in time. If you have supplies of 100 percent grain alcohol, mix 70 ml of alcohol with each 30 ml of water to make a 70 percent preservative. If you use a denatured alcohol, look first at the label on the bottle. It probably is 70 percent alcohol as it comes to you, and if so, you do not need to add any water.

PRESERVING IN FORMALIN If you use *formalin* (*for*-muh-lun) as a preservative, your teacher will no doubt make the proper solution by adding 10 ml of commercial formalin to each 90 ml of water. Be careful with formalin, for it is very strong and may irritate the skin. When you remove a specimen from formalin solution, wash it off right away, and wash off any formalin that may get on your hands. Be very careful that you do not get any formalin in your eyes.

RAISING PLANTS

One thing you may have need for early in your biology course is a supply of young plants. This is usually not hard to provide if you have some flower pots, soil, and seeds. You will also need a growing shelf next to a window. Be sure that enough sunlight is admitted to provide for the energy needs of green plants.

Various plants are likely to prove useful, but you should not fail to get a few bean and geranium plants off to an early start. To do this, simply fill several flower pots with fertile soil, and plant two or three seeds to a pot. Bean or other large seeds should be planted about an inch in the soil, and geranium and other small seeds should be

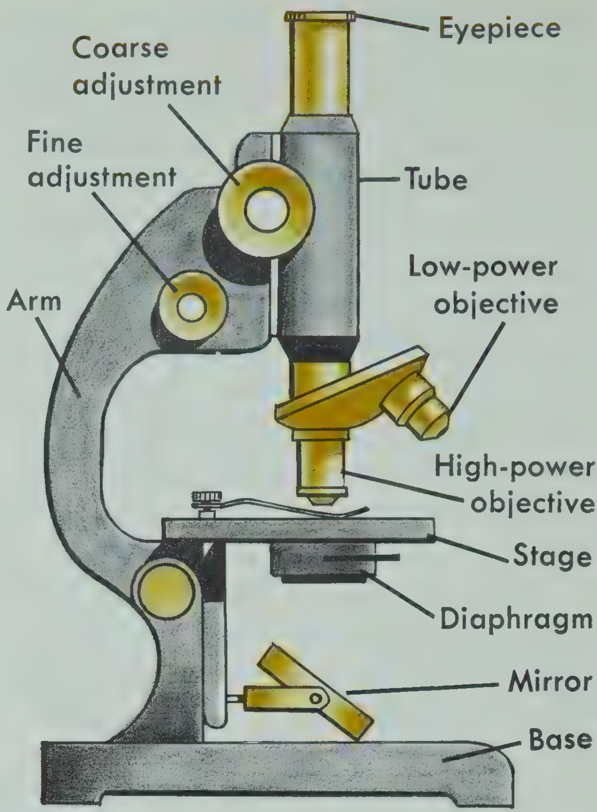
planted about a third of an inch in the soil. Water the plants regularly, so that the soil remains moist but not muddy.

If there is doubt about the fertility of the soil you use, a little commercial fertilizer should be mixed in with it. Such fertilizers can be obtained in city stores or markets, as well as from biological supply houses.

Not all seeds will sprout, of course, and another approach is to first test their sprouting ability. You can do this by placing several layers of white blotting paper or paper toweling in a shallow tray which contains water. The water should not come up over the top layer of the paper, but there should be enough in the tray to keep the top layer wet at all times. Now scatter the seeds over the wet paper surface, pressing them down into the soft paper pulp if they are large seeds. Cover the container with a plate of glass or sheet of plastic and set it aside, but keep it under close observation after the first two days. When the seed cases begin to split you will know that they are about to sprout. Plant such seeds in the moist soil of flower pots or growing trays.

USE OF THE MICROSCOPE

A microscope with its main parts labeled is shown in Fig. L–4. Such a microscope is a valuable instrument, and can be damaged by careless handling.



L–4. Diagram of a microscope.

CARE OF THE MICROSCOPE Always carry a microscope by the arm, and preferably with your free hand under the microscope base to give added support. When you put the microscope on a table, set it down gently. Make sure it is far enough from the edges that there is no danger of it toppling off.

Use only *lens paper* to clean lenses, and do it gently. Do not use solvents to clean lens surfaces. If solvents get around the margins of lenses, they may dissolve the cement which holds the lenses in proper position.

When not in use, keep the microscope in a closed microscope case, or under a plastic cover. This is to prevent dust from accumulating on the instrument.

USING THE MICROSCOPE In learning to use a microscope, proceed as follows:

1. Place the microscope on a table where there is either a source of light

from a window or an electric bulb. Some of the newer microscopes have built in electric illuminators beneath their stages. If you have one of this type, all you need is a socket where you can plug it in and obtain electric current.

2. If your microscope is the mirror type, put the ***low-power objective*** in position beneath the tube, and adjust the ***diaphragm*** to its largest opening. Now look through the ***eyepiece*** as you turn the flat side of the ***mirror*** toward your source of light. Locate a mirror position that gives you a round, clear, white field of view.

3. Place a microscope slide bearing some specimen—almost any slide will do—on the stage of your microscope. Center the specimen over the opening in the stage. Using the ***coarse adjustment*** move the tube downward until the tip of the objective is close to, but not touching the slide. Some of the newer microscopes have automatic stops so that the objective cannot be jammed against the slide. But other microscopes do not have this feature, and in this case great care must be taken to avoid damaging the objective and the slide. For this reason watch from the side when you lower the tube, rather than through the eyepiece.

4. Now look through the eyepiece again, and focus upward until the object on the slide appears. Bring it into sharp focus by turning the ***fine adjustment.*** Test the effect of the diaphragm by closing and opening it. Find the adjustment that gives you the best view of the object.

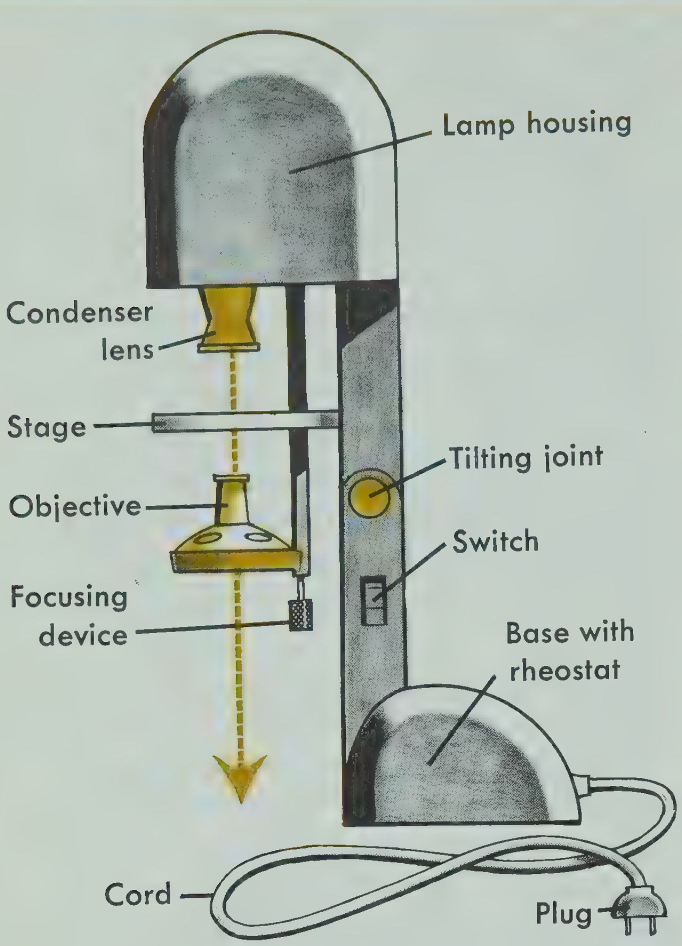
5. For many subjects the low-power objective is adequate, but for others you need the ***high-power objective.*** In any case, you first bring the object into focus under the low-power objective. If it appears that greater magnification is needed, center the specimen in the field, then look from the side and move the high-power objective into position beneath the tube. Reverse the mirror so that its concave surface is toward the source of light. Adjust the mirror and the diaphragm until the field is well lighted. Your object should be just about in focus, and you can now use the fine adjustment to make the focus sharp.

USE OF A SIMPLE PROJECTOR

Your school may have a simple projector like the one shown in Fig. L–5. Actually, this is just a microscope that can project images downward upon a piece of paper, or outward to a screen. The advantage is that the teacher and all the students can view objects together.

USING A SIMPLE PROJECTOR The projector drawing in Fig. L–5 shows only essential working parts. This instrument requires the same care as a microscope. As it appears in Fig. L–5, it is set up to project downward on a piece of white paper. But it can also be tilted at the tilting joint so that it projects onto a screen.

To use the instrument, position a slide on the stage, plug in the current, and turn the switch to the "on" position. Either then or before, you partially darken the room by drawing some of the shades. Now you use the focusing device to obtain a sharp focus.



L–5. Diagram of a simple projector.

Some of these projectors have one or more colored cooling glasses which can be moved into position above the stage. They are useful because they take the hot, red rays out of the light. As a result you can view small, sensitive, living cells for long periods of time. Some instruments also come with two or three objectives of different magnifying powers.

TEMPORARY MICROSCOPE MOUNTS

In studying biology, it is often desirable to make temporary mounts of small organisms or small parts of organisms. A temporary mount is not something that will keep indefinitely. You intend to use it as soon as it has been prepared. Afterwards, it is usually discarded.

MAKING A CROSS SECTION In studying the materials of Block I, you have made a number of simple, temporary mounts. Now you may wish to try something that requires a little more skill, such as preparing a cross section of a plant stem.

To do this you need a piece of bean stem, a watch glass full of water, a single-edged, sharp razor blade, a blank slide, a cover glass, a pipette, and either a forceps or a section lifter. Proceed as follows:

1. Cut a clean surface on one end of your bean stem. Make the cut as nearly at a right angle to the long axis of the stem as you can. Now begin to cut very thin slices or cross sections from the end of the stem. After you have practiced this several times you can probably cut reasonably thin sections.
2. As the sections are cut, dip your razor blade in the water contained in the watch glass, and wash the sections off into the water. You can use a stream of water from a pipette to free any sections that tend to remain on the blade.
3. Now select a thin, complete section, and lift it carefully out of the water, using a forceps or a section lifter. Center the section on a blank slide, cover with a cover glass, and you have a temporary cross section mount. If you want to keep it for a day or two, you can prevent drying by putting a drop of

mineral oil on the section before you put the cover glass in place.

Now you will wish to view the result with the aid of a microscope. Under low power you should be able to see the many cells that make up a plant stem. Since a bean plant has vascular tissues, you can locate the cells which form the ducts in the stem. In a bean stem these ducts make up a sort of broken ring near the outer surface of the stem.

STAINING A CROSS SECTION You can also learn to stain a cross section quite easily. Suppose you want to use two stains: one red, and the other blue. Two common stains are the red stain known as ***eosin*** (*ee*-oh-sun) and the blue stain known as ***gentian*** (*jen*-tee-un) ***violet.*** To stain one of your cross sections, proceed as follows:

1. Use a pipette to put a few drops of eosin solution in a watch glass. This should be a standard solution of eosin in water. Transfer a section to the eosin, and allow it to stain for about five minutes.
2. Wash the section briefly in water, and then stain it in gentian violet solution for two or three minutes. This should also be a standard solution of gentian violet in water.
3. Wash off the excess stain, and mount your section on a blank slide.

When you examine this stained section with the aid of a microscope, you may find that it is either too deeply or too lightly stained. If the section is too dark, try again, and shorten the staining times. If it is too light, try staining for longer periods.

PART II: DEMONSTRATIONS AND EXPERIMENTS

This portion of *Laboratory Investigations* includes various tests and experiments that are related to your study of Block I. For example, the first two experiments deal with physical factors of the environment, as discussed in Chapter 1.

PHYSICAL FACTORS OF THE ENVIRONMENT

You have learned that any environment includes both physical factors and living things. One of the most important physical factors is light, which usually means light from the sun. Sunlight provides the energy which green plants use in their basic food-making processes. You can test one effect of sunlight upon green plants by carrying out the following experiment.

SUNLIGHT AND PLANT GROWTH The first thing to do is to sprout some bean seeds as described on page 112 of this book. Plant five sprouting seeds in each of three growing trays that contain the same amounts of the same kind of soil. Add equal amounts of water to each tray every day so that the soil remains moist.

Put one tray on a window shelf where it will receive direct sunlight each day. Place the second tray on a table where it will receive light, but no direct sunlight. Put the third tray on a table, but under a box or other cover that will exclude all or nearly all light.

Check on the progress the plants make each day.

ANALYSIS After ten days have passed, prepare answers to the following questions in your notebook:

1. In which tray did the plants grow best?
2. How well did the plants grow in the tray which received little or no light?
3. What do you conclude about the relationship of sunlight to the successful growth of green plants?

HIGH TEMPERATURE AND LIFE Sunlight is related to temperature, because it is the sun's rays that bring warmth to our world. But some organisms do not fare well if they receive too much sunlight, and many of them are killed by high temperatures.

You can demonstrate one effect of high temperature upon simple organisms in the following manner. Place about 20 ml of pond culture in a test tube. This must be pond culture that you have already examined with the aid of a microscope. You must know that it contains a considerable number of single-celled and other small animals. Heat the test-tube contents slowly over a Bunsen flame until the liquid in the test tube comes to a boil. Set the test tube aside for a few minutes and let the liquid cool.

Now re-examine several samples of the heated culture with the aid of a microscope or projector. See if any living animals remain in these samples.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did you see any evidence that small animals survived in the culture after it was heated to the boiling point?
2. What do you conclude about the effect of high temperature upon simple animals?
3. How would you go about testing the effect of high temperature upon a culture of algae?
4. How would you plan a similar experiment to test the effect of freezing temperatures upon small animals?

CARBON COMPOUNDS

What you have read about proteins, carbohydrates, and fats in Chapter 2 has shown you that all of them contain the element carbon. In fact, the story of life is the story of carbon compounds. In its free form carbon is a black solid. You have seen common charcoal, which is largely made up of carbon.

A CHEMICAL CHANGE THAT RELEASES CARBON Oils will burn, whether they come from plant or animal sources. Begin this demonstration by soaking about four inches of soft, heavy cord or twine in corn oil. This is the same corn oil that you use for cooking. It comes from the corn plant, and is therefore a plant oil. The cord you use is plant fiber, and largely dried carbohydrate.

Now roll up your oil soaked cord, put it in a pan or some other suitable container, and light it with a match. It burns like the wick of an old-fashioned lamp. Hold the bottom of an empty test tube in the flame. See how quickly it becomes coated with a black film. This black film is carbon.

ANALYSIS Before trying to prepare answers to the following questions in your notebook, review what you have read about the compounds of protoplasm, and about chemical changes on pages 29–36.

1. What elements are found in fats? In carbohydrates?
2. Do you think that a chemical change took place when the oily string burned? Why?
3. You know that some carbon was deposited on the bottom of the test tube. What became of the rest of the carbon?
4. What became of the other elements that are present in fats and carbohydrates?

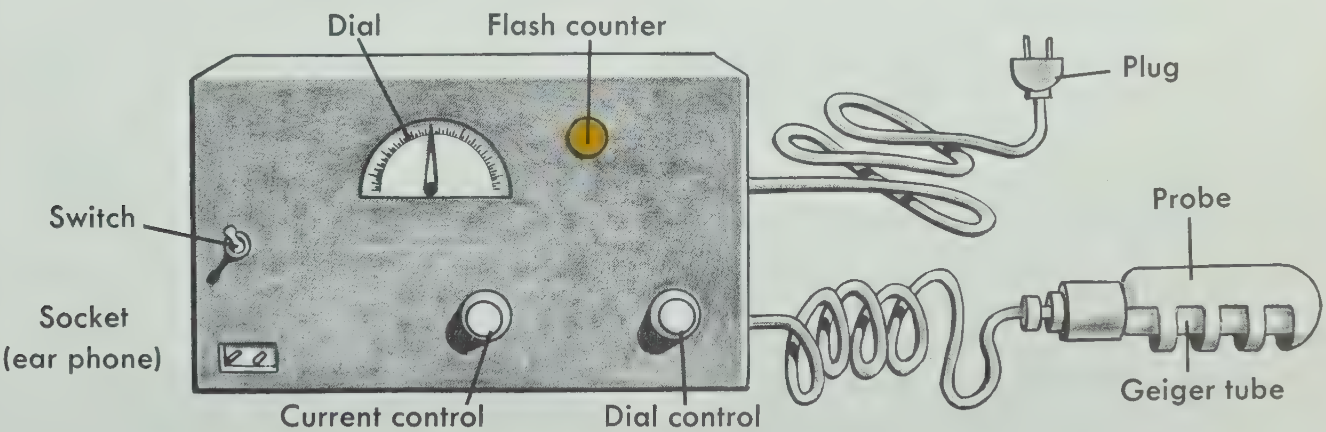
RADIOACTIVE SUBSTANCES

In Chapter 2, you learned that some atoms of certain elements are radioactive. This means that they give off small particles of matter, as well as energy, and that in time they break down into more stable elements. Any compound that contains radioactive atoms will prove to be radioactive when it is tested with an appropriate detector.

HOW YOU DETECT RADIOACTIVITY If your school has a Geiger counter, and someone has a watch with a radium dial (one that glows in the dark), your teacher may wish to carry out the following demonstration.

A Geiger counter is often like the one shown in Fig. L–6. Its sensitive part is a Geiger-Müller tube, which may be placed in a *probe* (see Fig. L–6) so that you can move it around and test various objects. Electrical impulses go from the Geiger-Müller tube to an internal mechanism which may register them in three different ways. First, when nuclear particles or energy reach the Geiger-Müller tube, a needle on scale *A* (Fig. L–6) moves over to register the amount of radioactivity. Second, a *flash counter* (*B* in Fig. L–6), which flashes when the Geiger-Müller tube encounters radioactivity, is often provided. Finally, a *clicking mechanism* is sometimes present (not shown in Fig. L–6), and an *earphone* may be plugged in so the observer can listen for clicks which indicate that the Geiger-Müller tube is near something radioactive.

To use the Geiger counter, you first plug it into a wall socket, just as you



L–6. Diagram of a Geiger counter.

would an ordinary lamp, unless your instrument is battery-operated. Then you adjust the dial control, probably so that the dial will register a very low rate of radioactivity. Now you turn the switch to the *ON* position. At this point you may be surprised to see the needle of the dial move over a short distance, thus indicating that radioactivity is present.

How can this be? Well, it is really very simple. There is, and has always been, a small amount of radioactivity in our environment. Rocks and soils contain radioactive compounds and so do plants and animals. Even your own body has some radioactive substances in it. The amount of this radioactivity usually is quite small. However, it is greater in some locations than in others, depending to some extent upon the kinds of rocks that are near the surface. The counts from natural radioactivity in any location is known as the *ground rate.*

So the first thing you determine when you are using a Geiger counter is the counts from natural radioactivity around you. Suppose, for example, that the needle on your dial hovers around number 2. This is the ground rate. Now you bring the probe close to a watch that has a radium dial. The needle on the dial may move to number *6*. You subtract the ground rate from 6, and find that the reading due to the watch dial was actually *4*. In other words, it was double that of the normal radioactivity in the place where you happened to be. If you have a watch with a radium dial, try this little test.

But remember one thing. The number of units the dial will register depends upon the setting of the dial control. If it is set to detect low radioactivity, the needle may move over a larger number of units. If, however, it is set to register high radioactivity, the needle may move only a short distance, if at all, because the units it now indicates are much larger.

ANALYSIS After observing and studying the operation of a Geiger counter, prepare answers to the following questions in your notebook:

1. Do you suppose that radioactive substances might enter your body in the things that you eat and drink? Why do you think so?
2. Suppose that you find that with the dial setting you use the ground rate in your classroom is 3 units. You watch the flash counter for a period of 5 minutes and find that 25 flashes occur in this period. Now you move the probe near a watch with a radium dial, and find that in the next 5 minutes 75 flashes occur. How many units would the dial be registering during this second 5-minute period?

LIVING MEMBRANES

You read in Chapter 3 that cells have membranes. The cell membrane surrounds the cytoplasm, and two membranes surround some nuclei. There are also membranes which extend from the cell membrane to the nuclear membrane, and divide the cytoplasm into compartments.

All of these membranes are semipermeable. Molecules in a solution are in a state of constant motion. They

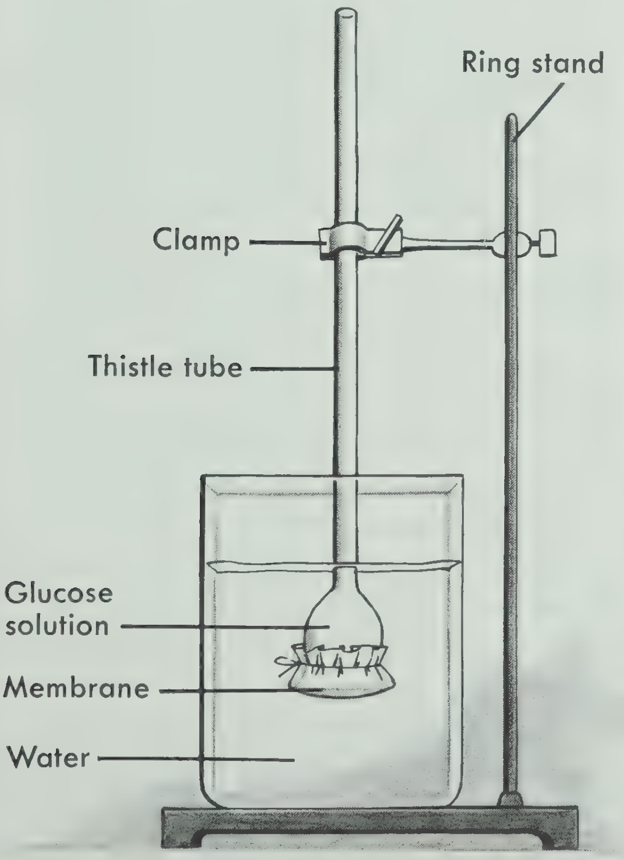
collide with one another, and they bounce off solid walls, but they keep on going. Now and then one of them hits a hole in a semipermeable membrane and goes through. A small molecule that moves rapidly is more likely to do this than is a large molecule that moves slowly.

AN OSMOSIS DEMONSTRATION The passage of water molecules through a semipermeable membrane is called *osmosis.* It is the way in which water molecules leave and enter many cells, as well as pass through membranes within cells.

You can demonstrate the process of osmosis by putting a solution containing small molecules on one side of a semipermeable membrane and a solution containing larger molecules on the other side. The solution of small molecules can be water. For a solution containing large molecules, use molasses, or any syrup which contains glucose.

As shown in Fig. L–7, fill the thistle of a thistle tube with the glucose solution. Hold it with the thistle end upward as you do this, and control the amount of glucose that enters the thistle by stopping the lower end of the tube with a finger. Now have someone else place a semipermeable membrane over the open end of the thistle, and fasten it securely below the rim of the thistle with rubber bands. Finally, insert the thistle tube in a battery jar full of water, clamping it to a ring stand as shown in Fig. L–7.

As soon as the apparatus is completely set up, note how far the glucose solution comes up in the thistle tube. Then watch to see what happens. Before long you can see that the level of the glucose solution is rising. With a short tube like the one shown in Fig. L–7, the glucose solution will finally run out of the top of the tube and down into the battery jar.



L–7. A demonstration of osmosis.

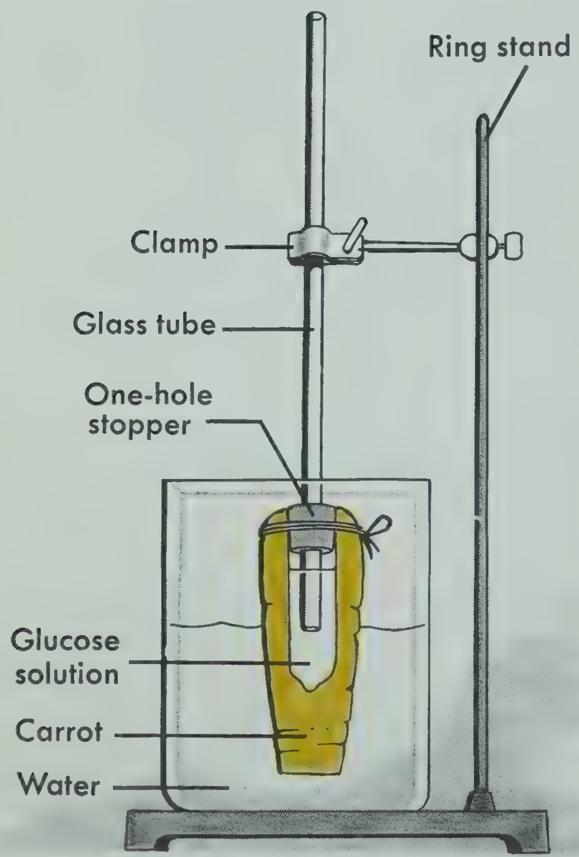
ANALYSIS After completing this observation of osmosis, prepare answers to the following questions in your notebook:

1. What caused the level of the glucose solution to rise in the thistle tube?
2. Were water molecules passing from the battery jar to the glucose solution in the thistle tube? What evidence do you have?
3. Were glucose molecules from the

thistle tube passing out into the battery jar water? How do you know?

4. If you left this apparatus in place, would the action continue indefinitely, or come to a stop? Why do you think so?

OSMOSIS IN A CARROT ROOT The membrane you used in the previous demonstration probably was man-made. In other words, it was nonliving. Living, semipermeable membranes behave in much the same way, but with one important difference. A living membrane tends to allow the passage of certain molecules but restricts the passage of other molecules. So you may want to try a similar experiment in which you use the living membranes of cells in a carrot root.



L–8. Osmosis in a carrot root.

Begin by using a cork hole-borer to cut out a cavity extending downward from the top of a carrot, as shown in Fig. L–8. Fill this cavity about half full of molasses or any other glucose solution. Fit a one-hole stopper that contains a piece of glass tubing into the cavity at the top of the carrot, and tie it in place *tightly* with several strands of string. There must be no leakage around this cork. Cut off the tip of the carrot root so that water is in contact with the root ducts. Now set up your apparatus so that the carrot is partially immersed in the water, as shown in Fig. L–8.

You probably will have to wait overnight to get good results. After all, there are a good many cells between the glucose chamber in the carrot root and the battery jar water on the outside. But in time you should see the glucose solution rise in the glass tube.

ANALYSIS After you have completed the demonstration with the carrot root, prepare answers to the following questions in your notebook:

1. What caused the glucose solution to rise in the glass tube? Explain your answer thoroughly.
2. Do you suppose that any glucose molecules will be found in the water in the battery jar? How could you test this?
3. Do you think that more than one membrane was involved in the passage of water molecules from the battery jar to the glucose chamber? Give reasons for your answer.

BEHAVIOR OF PARAMECIUM

In studying Chapter 3, you learned a number of things about the little, single-celled organism called paramecium. If you have a culture of living paramecium, you can perform the following behavior demonstration.

A REACTION TO EOSIN No doubt you have already seen the red stain eosin which will be used in this experiment. You also will need either a microscope or a projector, like that described on page 113. A projector is better in this case because a number of people, including your teacher, can see what is happening.

Place a drop of culture on a blank slide, but do not use a cover glass. Focus upon the sample with low power, and find a place where you have a number of paramecia in clear view. Now use a dissecting needle to pick up a droplet of eosin, and insert the eosin at the edge of the culture drop. Keep watching, and see how the red stain spreads through the culture drop. Usually this is fairly slow, and you have a chance to see how the paramecia react.

Eosin in the water acts as a strong stimulus. The paramecia respond as soon as they come in contact with the stain. Observe their responses, and see what happens to them over a period of time.

ANALYSIS After completing this observation of behavior, prepare answers to the following questions in your notebook:

1. In general, are paramecia attracted to the eosin in the water, or do they tend to avoid it?
2. What happens to a paramecium that has absorbed a lot of eosin?
3. What do you suppose would happen if you used iodine solution in this experiment instead of eosin?

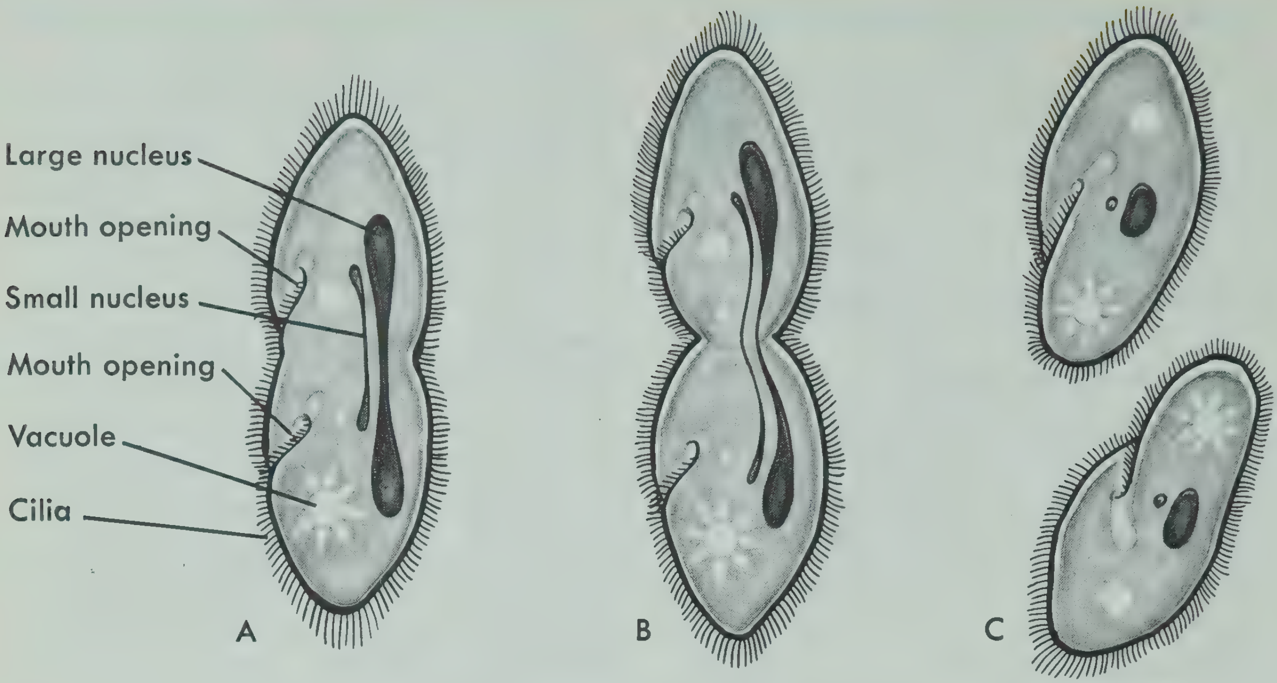
FISSION IN PARAMECIUM In a favorable environment, a paramecium will feed actively upon various small organisms, including bacteria. It soon reaches full size, and then it usually divides through its *short axis.* Its nuclei divide first, but this is soon followed by division of the cytoplasm, as shown in Fig. L–9. This simple type of cell division is called ***fission*** (*fish*-un).

This sort of growth and division may keep up for about 50 generations. Then it tends to slow down, whereupon two paramecia may come together and ***conjugate*** (*conn*-juh-gate). The two cells lie side by side for a period of time, during which they exchange *nuclear materials.* Then they separate, and each of them is able to grow and divide for about another 50 generations.

If you have some microscope slides which show paramecium in various stages of fission, examine them carefully. Samples taken from a good culture of living paramecium may also contain a number of cells that are dividing.

ANALYSIS After observing a number of paramecia in various stages of fission, prepare answers to the following questions in your notebook:

1. In what way is the growth of a paramecium related to fission?



L–9. Stages in the division of a paramecium. This species has one large nucleus and one small nucleus.

2. How do the two new cells that result from fission differ from the parent cell?
3. What function does conjugation appear to serve?

STORED STARCH IN GREEN LEAVES

You have studied the food-making process of green plants in Chapter 3. Leaves are the food-making centers of most higher plants. Among the basic foods are simple sugars, which often are converted into starch and stored in that form. If a leaf is unable to make foods for any reason, its supply of stored starch is likely to be exhausted before long.

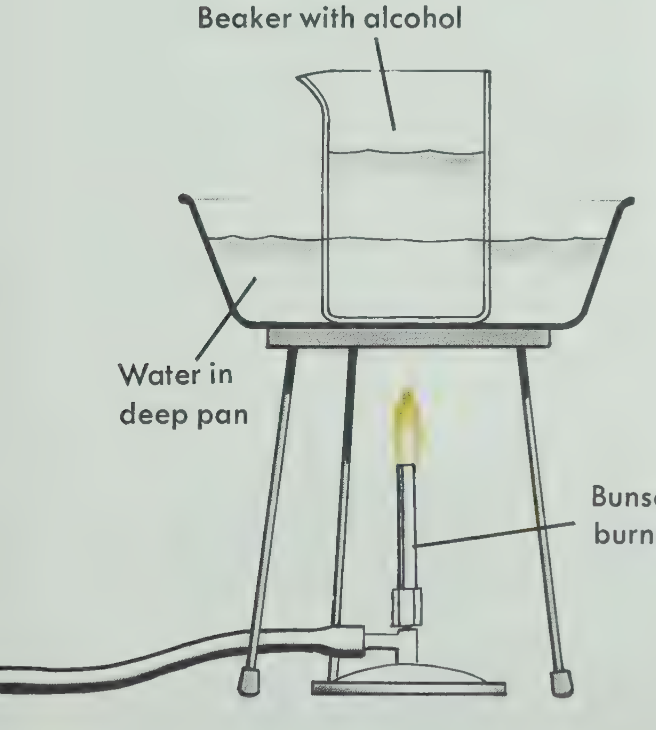
TESTING FOR STARCH IN GREEN LEAVES Since you have learned to test for starch (see page 33), you can get some first-hand evidence about stored starch in leaves. Select a geranium plant that is growing in a well-lighted place, and tie an opaque bag around one of its leaves. Call this *leaf A,* and leave it covered for a day. Since it receives no sunlight, its food-making processes will be halted, except for the dark phase of photosynthesis.

To test any leaf for starch, you must first remove its pigments. If the leaf is first heated in water, the cell walls will break up, and it will be easier to extract the chlorophyll. Then the leaf should be heated in alcohol. The safe way to do it is to use a water bath as shown in Fig. L–10. You heat the water in the pan, and the water heats the alcohol in the beaker. When you put a green leaf in the beaker, the alcohol soon absorbs the green pigments, as well as other pigments that may be present, and the leaf becomes white.

Select a leaf that has been in bright sunlight. Call this *leaf B*. Extract the chlorophyll from the leaf in hot alcohol. Then use a pipette to put some iodine solution on the leaf. Wait two or three minutes to see if the blue-black color which indicates the presence of starch appears. Now repeat the process, using *leaf A*, which has not been in the sunlight for a time.

ANALYSIS After you have carried out the starch test on the two leaves, prepare answers to the following questions in your notebook:

1. In which leaf did the largest amount of starch appear to be present?
2. What do you think happened to most of the starch in *leaf A* after this leaf was kept in darkness?



L–10. A diagram that illustrates how to heat alcohol in a water bath.

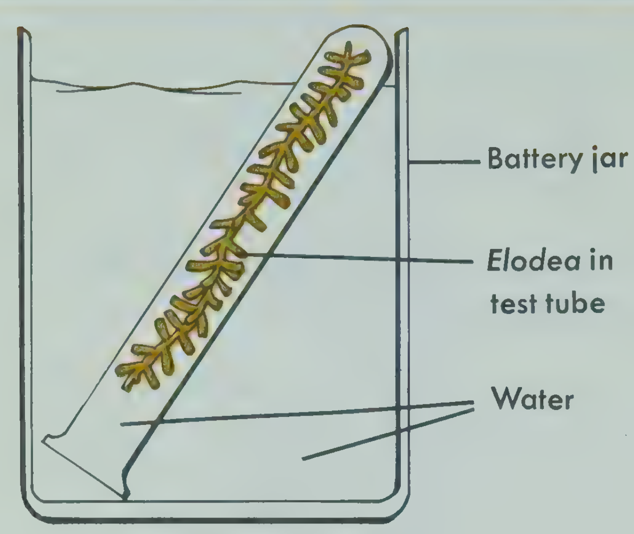
3. Do you think *leaf A* would show the same results if it were kept in a place where it received strong artificial light, but no sunlight? How could you find out?

DISCHARGE OF OXYGEN BY AN ELODEA PLANT

On pages 26–27, you read some things about cells of an *Elodea* plant, and on page 50 you learned that a green plant gives off extra oxygen when it is making foods. *Elodea* is a plant that lives in the water. Does it discharge oxygen when it is actively making foods?

COLLECTING OXYGEN UNDER WATER You can get an answer to this question easily enough. Begin by placing a battery jar full of water on a well-lighted growing shelf. Put a sprig of *Elodea* in a test tube, and fill the test tube with water. Hold your thumb over the test tube opening so that the water cannot escape; then invert the test tube in the battery jar of water, as shown in Fig. L–11. Examine what is happening in the test tube from time to time. Do you see any bubbles rising from the *Elodea* leaflets?

After the *Elodea* has been exposed to sunlight for a day or two, you will see quite a change. The bubbles of gas that come from the leaves rise up to the bottom of the inverted test tube. Here they collect, and as they do, water is forced out of the lower end of the test tube. After some time has passed you may find about an inch of gas collected in the closed end of the tube. Some of this gas is oxygen that has been discharged by the *Elodea*.



L–11. Observing the discharge of oxygen by an *Elodea* plant.

ANALYSIS After observing the discharge of gas bubbles by an *Elodea* plant, prepare answers to the following questions in your notebook:

1. A green plant uses water (H_2O) and carbon dioxide (CO_2) in its food-making process. From which of these compounds do the oxygen bubbles come?
2. Do you think oxygen bubbles would continue to rise from the *Elodea* leaflets if the room were dark? How could you get evidence?

PLANT PIGMENTS

Many plants contain green pigments known as *chlorophylls.* In addition, green plants contain other pigments which are red, orange, and yellow in color. In many cases these pigments cannot be seen because they are masked or hidden by the abundance of chlorophyll.

SEPARATING PLANT PIGMENTS Whether a leaf appears green or not, other pigments are often present. You can demonstrate this in the following manner. Begin by chopping up some beet leaves into tiny pieces, which, except for their stems, look quite green. Put the chopped leaves in a beaker of alcohol, and heat the alcohol in a water bath, as shown in Fig. L–10. You will soon find that your alcohol has turned a bright green color. Surely it contains a lot of chlorophyll, but does it contain any other pigments?

To answer this question, pour some of the green-colored alcohol into a beaker and allow it to cool. At this time make sure that there is no lighted Bunsen burner or other fire in the near vicinity. Now put 50 ml of the green extract in a test tube and add 10 ml of water. Then add 60 ml of benzol (also known as petroleum ether) to the contents of the test tube. Stir the contents of the test tube with a stirring rod. Finally, pour the liquid into another test tube that is set up in a vertical position. Wait a few minutes to see what happens.

The liquids in the test tube soon form *two layers.* One of these layers is green. It is the layer that contains the chlorophyll pigments. The yellow, orange, and red pigments are in the other layer.

ANALYSIS After carrying out this demonstration with beet leaves, prepare answers to the following questions in your notebook:

1. Did the upper or the lower layer contain the chlorophyll? What color was the other layer?
2. Do you know any leaves that contain enough red pigment to make

them look red? Do you suppose that these leaves also contain chlorophyll? How could you find out?

CONJUGATION IN SPIROGYRA

The *Spirogyra* you read about in Chapter 4 lives as a filament of cells. The cells of such a filament can grow and divide to make more cells. But this does not produce more filaments, unless some of the filaments are accidentally broken in two.

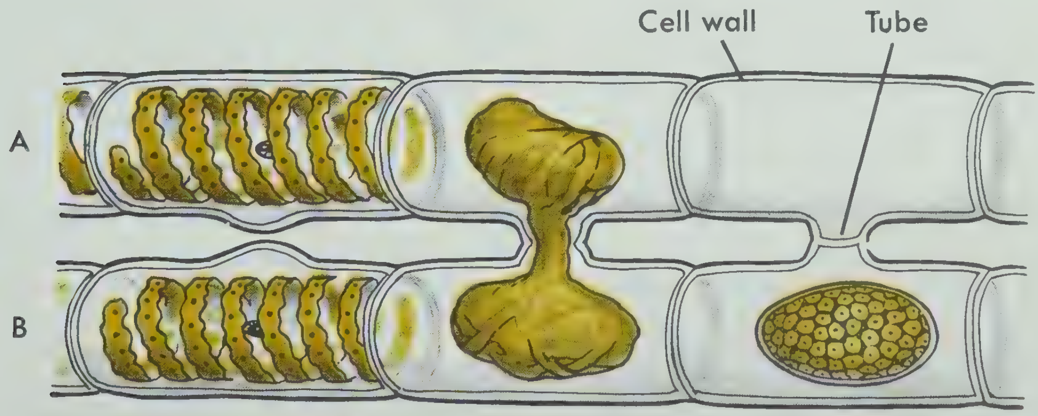
SPECIAL SPORE CELLS *Spirogyra,* however, does have a natural method of producing new filaments. It depends upon the development of special spore cells. If you have a microscope slide that shows two *Spirogyra* filaments conjugating, you can use a microscope or a projector to see how these spore cells are formed. An active culture of *Spirogyra* in the spring or fall may also contain filaments that are either conjugating, or have completed this process.

When you examine such materials, you find filaments lying side by side as shown in Fig. L–12. Small tubes form between adjacent cells. Then the living material of one cell, including both cytoplasm and nucleus, passes into the other cell of the pair. Thus, in Fig. L–12, the materials of *filament A* have passed into, and united with the materials of *filament B.* A special type of spore cell is formed.

As a general rule, all of the cell materials of *filament A* are passed over to cells in *filament B,* and the cells of *filament B* become spore cells. *Filament A* is left as a strand of empty cells. But exceptions to this general rule are known to occur. Also, cells of some filaments may become spore cells without having received materials from other cells.

A spore cell develops a heavy outer covering, and drops to the bottom of the pond. Here it remains in a resting stage. All the same, the cell contents are active, and are being reorganized. After a period of time, which may last as long as a year, the spore cell loses its heavy, outer covering, and begins to grow and divide. In time, it gives rise to a new filament.

ANALYSIS After observing materials that show various stages in the conjuga-



L–12. The formation of special spore cells occurs when *Spirogyra* conjugates.

tion of *Spirogyra,* prepare answers to the following questions in your notebook:

1. If you were to say that *filaments A* and *B* in Fig. L–12 are male and female, which one is female, and why?
2. How does a spore cell differ in appearance from an ordinary *Spirogyra* cell?
3. How would you define the term "spore cell"?

BREAD MOLD

You have had an introduction to molds in your study of Chapter 4. Samples of common bread mold can usually be prepared without much difficulty. Proceed as follows:

1. Place layers of moist paper toweling in a half dozen petri dishes. Have three or four thicknesses of the paper in each dish.
2. Put a slice of stale bread, that has been exposed to the air for some time, on top of the paper in each petri dish.
3. Put the covers on the petri dishes, and keep them in a warm place, but where they are not in direct sunlight.

OBSERVATIONS OF BREAD MOLD Examine the bread slices daily, and record what you observe in your notebook. If bread mold appears it will first look like a fuzzy whitish substance on the bread surface. Later on, the dark-colored spore cases you read about on page 65 begin to develop.

Using a hand lens, examine samples of the bread and mold. Locate hyphae, stolons, and spore cases. Observe how the hyphae that are known as rhizoids penetrate down into the bread.

ANALYSIS After observing the development of this mold until its spore cases have formed, prepare answers to the following questions in your notebook:

1. At what time did the mold spores probably get on your bread slices? Where do you think the spores came from?
2. What special functions do you think are carried out by the rhizoids? Remember that the growing mold must have food and water.
3. To what extent is there division of labor among the different kinds of hyphae?

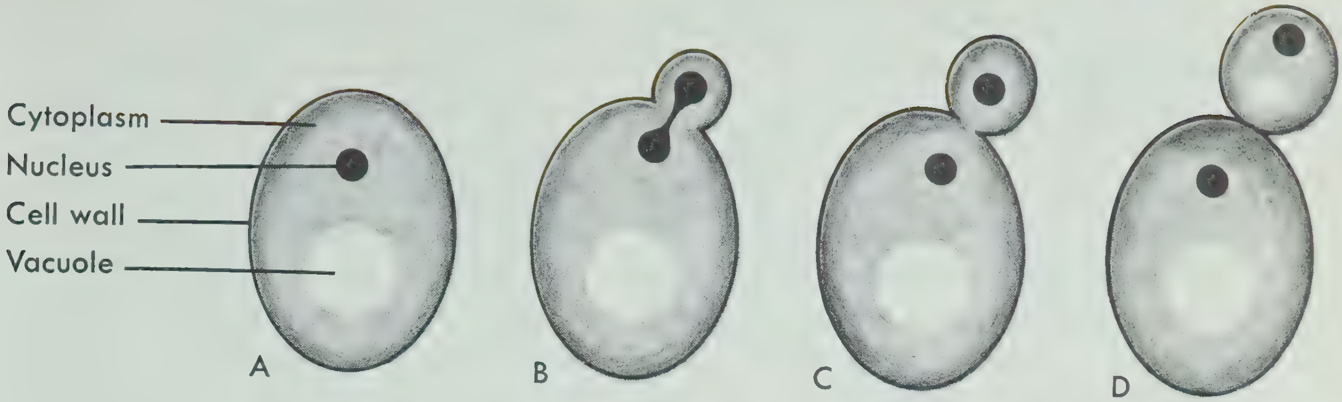
THE BUDDING OF YEAST CELLS

Yeast cells are one type of the fungi you studied in Chapter 4, and they are so small that you need the high power of a microscope to see them well.

REPRODUCTION OF YEAST CELLS Carefully prepare an active culture of yeast cells, following the method described on page 154. This should be done three or four days in advance, so that the yeast cells have sufficient time to grow and multiply.

Make temporary slides of culture samples, and examine them with the aid of a microscope. You should see many full-grown cells like *A* in Fig. L–13. Each cell has a cell wall, a cytoplasm, a large vacuole in the cytoplasm, and a nucleus.

In your culture sample, you probably will find a number of cells that are producing buds, as shown in *B, C,* and *D* of Fig. L–13. This is one way that yeast cells commonly reproduce. Some-



L–13. (A) A mature yeast cell; (B) a small bud is forming, and the nucleus is dividing; (C) division of the nucleus is complete; (D) the bud is virtually separated from the parent cell.

times a group of buds remains attached to the *parent cell* and forms a sort of *colony*. But in other cases the buds separate from the parent cell, grow, and produce buds of their own. This type of reproduction is called *budding*.

Yeast cells also have another way of reproducing, which occurs when conditions of the environment are *unfavorable*. In this case the living contents of the yeast cell divide to form small cells which are equal in size, and are usually four in number. These small cells are one type of spore, and they remain within the original cell wall until conditions of the environment become favorable again. When the spore cells begin to grow, they break through the old cell wall, and they become active yeast cells.

ANALYSIS After examining yeast cells that are budding, prepare answers to the following questions in your notebook:

1. How does the budding of a yeast cell differ from the cell division of a paramecium?
2. Yeast cells are not food producers. Where do they get the food that is necessary for growth?
3. Do you think yeast cells could grow and reproduce in the dark? Give reasons for your answer.

EARTHWORMS

The earthworms that you studied in Chapter 4 are invertebrates that spend most of their lives burrowing in the soil. They have tissues, organs, and body systems, but they have no organs of sight or hearing.

BEHAVIOR OF AN EARTHWORM Examine a living earthworm with the aid of a hand lens. Find the mouth opening at one end of the body, and the anal opening at the other end. Hold the worm gently between your thumb and first finger. Locate the short bristles along its sides, and observe them through a hand lens. Be sure to keep the worm moist. A few drops of water from a pipette may be used as needed.

Place the worm on some soft, moist soil. Observe its behavior as it attempts to dig down into the soil.

Put the worm on some moist paper toweling. Touch the worm's head end gently with a toothpick. See how the worm responds. Try touching the worm on other parts of its body.

Keep the worm on moist paper toweling in a darkened room for five minutes or more. Now direct a beam from a small flashlight on the head end of the worm. How does the worm react?

ANALYSIS After completing these observations, prepare answers to the following questions in your notebook:

1. What function might be served by the bristles on the sides of an earthworm?
2. Are earthworms sensitive to what happens in their surroundings? Although they have no eyes, are they sensitive to light? What evidences do you have?
3. An earthworm has no lungs or gills. Yet it must get oxygen from the air in order to live. How do you think this is done?

DISSECTING AN EARTHWORM You learned some things about the internal structures of earthworms when you studied Chapter 4. In order to see these structures, however, you must dissect an earthworm.

Begin by placing a preserved worm on a sheet of cork board, or on the paraffin surface in a dissecting tray. Supply yourself with a sharp scalpel, a fine-pointed scissors, a forceps, a dissecting needle, and a number of common pins.

Use your scalpel to make a small slit in the upper mid-line of the worm's body wall, starting near the head end. Now use the fine-pointed scissors to cut through the body wall for two or three inches along the upper mid-line. Be careful not to damage internal structures any more than necessary.

Right away, you will see the *digestive canal*, which runs the length of the body, and occupies much of the space in the body cavity. The body cavity, between the digestive canal and the body wall, is divided into many little compartments which correspond to the segments. You must use your scalpel to cut through the thin muscular walls that form the partitions between the segments. Now you can pin down the two sides of the body wall, and observe some of the internal structures.

Refer to Fig. 4–17 on page 73, and locate the *pharynx, esophagus, crop, gizzard*, and *intestine*. Find the *large blood vessel* lying in the body cavity just above the digestive canal. Locate the five pairs of "hearts" which pass around the esophagus. These "hearts" connect the large blood vessel above the digestive canal with a similar blood vessel that lies below the digestive canal. You also may discover some white-colored glands lying alongside the esophagus. In fact, you may have to carefully remove them with a forceps in order to clearly see the "hearts."

Use your forceps to push a portion of the digestive canal out of the way. Look along the lower surface of the body cavity in the mid-line. See if you can find the *nerve chain*. This is the main control-center in an earthworm's body. Use a hand lens if necessary.

ANALYSIS After completing this dissection, prepare answers to the following questions in your notebook:

1. How do you think oxygen and digested foods reach the many cells of an earthworm's body? How do you think wastes are removed from these cells?
2. What part directs an earthworm's actions? Does an earthworm "think" about its reactions? Give reasons for your answers.

THE GROWTH OF BACTERIA

Bacteria are very small, and they are also very numerous. You encounter them everywhere: in water, soil, air, and in the bodies of plants and animals. Chapter 5 gives us an introduction to many protists, including the bacteria.

A CULTURE OF BACTERIA Since bacteria are just about everywhere in our environment, it is usually quite simple to obtain cultures of them. One method is to put about a dozen dry beans in a glass or jar of water. Leave the glass in a warm, dimly lighted place for about two days, or until the water in the glass turns cloudy.

Now use a pipette to put a drop of the cloudy water on a blank slide. Cover it with a cover glass. Using the high power of a microscope, you should be able to see many bacteria. They are feeding upon the substance of the decaying beans.

STAINING BACTERIA Usually you can see bacteria better if they have been stained. To do this, proceed as follows:

1. Place a drop of the cloudy water on a blank slide. Use a toothpick to spread the drop evenly over an area about the size of a five-cent piece. Let the water dry.
2. Pass the slide rapidly through a flame two or three times—bacteria side up. When you have finished, the slide should feel warm, but not so hot as to burn your fingers.
3. After the slide has cooled, use a pipette to put two or three drops of the stain known as *methylene blue* on the bacteria. Allow the stain to remain for two or three minutes.
4. Use a pipette and water to gently wash away the excess stain. Let the slide dry again.
5. Use the high power of the microscope to examine your stained specimens.

ANALYSIS After completing the foregoing observations, prepare answers to these questions in your notebook.

1. Where do you think the bacteria in the bean water came from? How sure are you? How would you test your answer?
2. What shape were the bacteria you observed? Were they single cells? Were they able to move about?
3. Did the bacteria appear to have nuclei? Explain.

BACTERIA AND MOLDS

Bacteria are like molds in that most bacteria cannot make foods. Also, many bacteria and molds feed upon decaying plant and animal materials. Spores of both bacteria and molds are in the air and in the dust at our feet.

BACTERIA, MOLDS, AND DECAY Here are some conditions that favor the growth of bacteria and molds:

1. Put a piece of very ripe fruit, such as a piece of a banana, in an open jar.
2. Put a few crushed grapes in a culture bowl full of water.
3. Put some flower stems in a culture bowl full of water. Hay stems or dried grass may also be used.
4. Put a teaspoonful of cottage cheese in a culture bowl full of water.
5. Mix some soil into a thin paste made of cornstarch and water. Place some of this mixture on paper toweling and keep it moist.

Put all of your samples in a warm, dimly-lit place. Do not cover the culture bowls. Make regular observations of the materials. When growths appear, examine samples under high power.

ANALYSIS After completing your observations, prepare answers to the following questions in your notebook:

1. What was the most common form of life to appear in each sample?
2. Which form of life appeared to grow under the greatest variety of conditions?
3. What happened to the plant and animal materials in the samples as the organisms grew?
4. Why do you think foods decay?

PART III: STUDY OF A POND COMMUNITY

Living things seldom are found alone. Instead, they are generally found in groups. For example, a group of frogs may live in a pond, a group of earthworms in a plot of soil, and a group of ducks in a marsh. A group of the same species, living closely together, is called a *population.*

Populations also live in *groups.* A population of one kind of fish, or of one kind of frog, or of one kind of water insect may live in a pond. Here they are associated with other populations, including populations of aquatic plants. Such a group of populations living in the same place is called a *community.*

Communities exist wherever living things are found. Thus, there are communities in ponds, forests, and marshes, and on prairie lands and deserts. The boundaries of many of these communities are often somewhat vague, because they tend to overlap. Thus, a pond community and the surrounding land community contain a number of species that are likely to be found in both locations.

This portion of your textbook is planned to help you carry on an investigation of a pond community. By following the directions, you will gain experience in observing, collecting, culturing, and preserving. You will also gain knowledge about living things and how they are related to one another.

If you glance through the following instructions, you will see that they are divided into sections. One section describes how to select a pond community, and how to begin your study. Another deals with observing, collecting, culturing, and preserving specimens taken from the community. A third section gives directions for making a detailed study of an organism, and

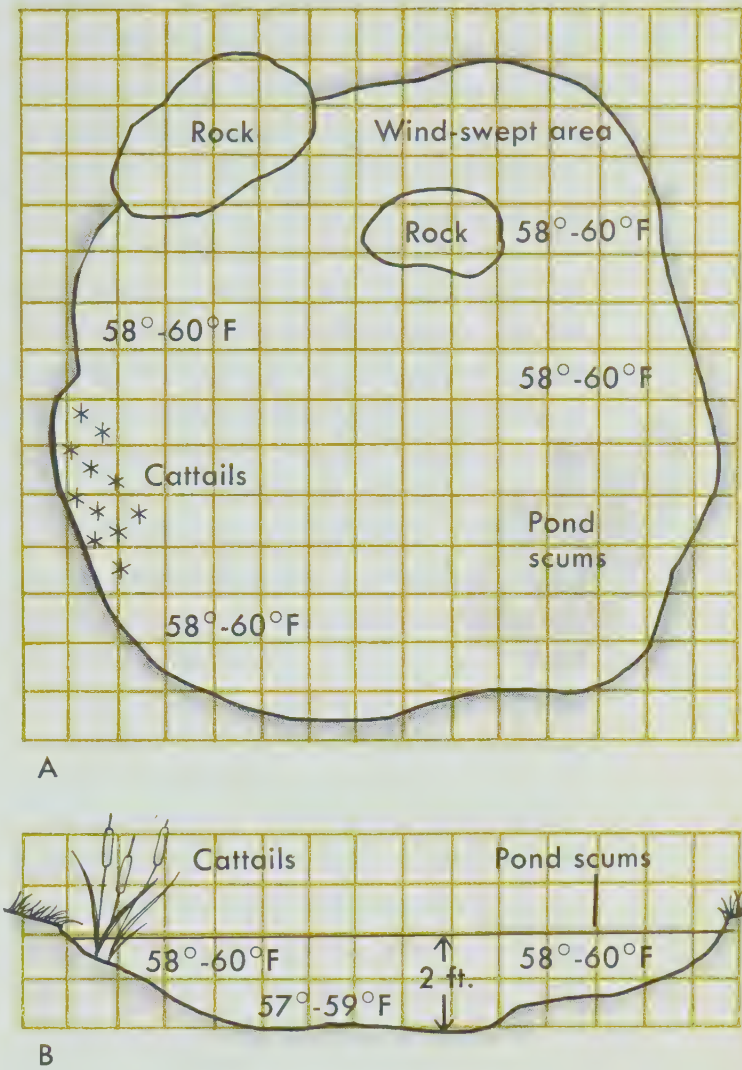
the role it plays in community life. The final four sections provide an opportunity to learn how living things are affected by certain nonliving factors of the environment.

SELECTING A COMMUNITY FOR INVESTIGATION Almost any freshwater pond, or a portion of a stream, lake shore line, or marsh will be suitable for study. Even a ditch with a little water in it or a small fish pool can be used. Each of these places will exhibit a special set of conditions, and its own group of populations. However, any community that contains a variety of living things will be more interesting than one that includes only a few types.

If the pond or other area is small, you may wish to study all of it. If the area is large, you will need to decide how to limit your investigation. One method is to study a number of small, sample areas that lie within the larger area. After you have decided, it is a good idea to mark the area or the sample areas with stakes and string so that you have visible boundaries; then stick to these boundaries throughout your investigation.

Begin your study by making a map of the area you have selected. Include all of the obvious features: the shore line, rocks, reeds, mats of pond scum, and other water plants. Visit the area at different times during the day to see what changes take place in lighting. If some parts are shaded more than others, indicate this on the map. If some parts are more exposed to wind action, indicate this also.

Use a thermometer to measure the temperature of the water just beneath the surface. Get a reading at several places, both in the morning and in the late afternoon, and record your findings on the map. Does the temperature change during the day? Overnight? How much? After you have finished, your map should be more or less like Fig. L–14A.



L–14. (A) Map of a small pond selected for study of a pond community. (B) Cross-sectional map. (Each box represents one square foot.)

You also may wish to make a *cross-sectional* map of your area. It will show the slope of the shore line and the

bottom. You can record the depth of the water, and indicate the locations of the larger water plants. The temperature of the water at various depths can also be taken and recorded on the map. See Fig. L–14*B*.

POPULATIONS OF THE COMMUNITY Rather than collecting the larger kinds of living things, you probably will want to restrict your study to making careful observations. These observations can be recorded in your notebook. For each kind of organism, you should note where it was located, the number seen, the activities of the organisms, and how they seemed to affect other living things. The observations can be summarized in a chart like the one below.

It is not always necessary to know the exact species of plant or animal that you observe. For instance, there are various species of algae that form mats on the surface, and for purposes of this study, you can treat all of them as pond scums. The same rule also applies to the different species of frogs, minnows, small turtles, and aquatic worms.

You will need to collect pond cultures including small organisms at various points in the pond area. To do this, you need the equipment pictured on page 108. You can observe some of the organisms in such culture materials right out in the field. But others must be studied back in the classroom where you have the use of a microscope. Never collect more than you plan to use in your study. When you have observed the materials, return the living forms to the area where you found them.

There are a number of useful guides that will aid you in finding out what kinds of plants and animals you have collected. Some of them are listed on page 141 of this book.

You may wish to keep some of the higher plants that grow in shallow water, so that you can have more time to examine them. One way to do this is to put two or three inches of sand in a battery jar full of pond water, and root the plants in the sand. Do not put too many in a single battery jar, and keep the jars where they get good light, but where the water will not become too warm.

No doubt you will find a number of small, aquatic animals that you can see without the aid of a microscope. These can be kept temporarily in jars of pond water, or they can be kept for longer periods of time in an aquarium, like that described on page 254–255. In any case, the water should be on the cool side, and you have to remember that some of the larger animals are likely to eat the smaller ones.

Specimens of plants and animals, that you wish to keep for a long period of time, can be preserved in 70 percent alcohol or 10 percent formalin.

In the pond cultures that you collect will be many tiny forms of life. The best

Organism	Location	Number seen	Activities	Other notes

way to examine these materials is to make temporary slides of culture samples, as described on page 114. Then use a microscope or a projector to examine the slides. The little organisms you see are likely to include algae, protozoa, aquatic worms, insects in various stages of development, and small relatives of the crayfishes.

Without doubt, bacteria are also present in your culture samples. Do not fail to examine some of the culture materials under the high power of a microscope.

When you have completed your survey of the plants and animals, you may be surprised by the variety of things you have found. Your list is likely to be longer than you would have believed possible. Try to estimate the extent to which each type of life was represented. Was it abundant, common, or uncommon?

THE ROLES OF COMMUNITY MEMBERS Your teacher may wish to assign types of pond organisms for individual study. You might make a study of a crayfish, a snail, or an aquatic insect. Observe it carefully for a period of time. Watch what it does, what it eats, where it goes, how it acts under special conditions, how it affects other living things, and how it is affected by them.

Using available reference books, find out as much as you can about this organism. Summarize your findings by writing a report describing the role the organism plays in the community. Also, describe the ways in which it is adapted to life in a pond community. That is, does it have a shape that allows it to move easily through the water? Does it have special structures for swimming? Does its color serve to hide it when it is in the water? Does it have special ways of getting oxygen from the water?

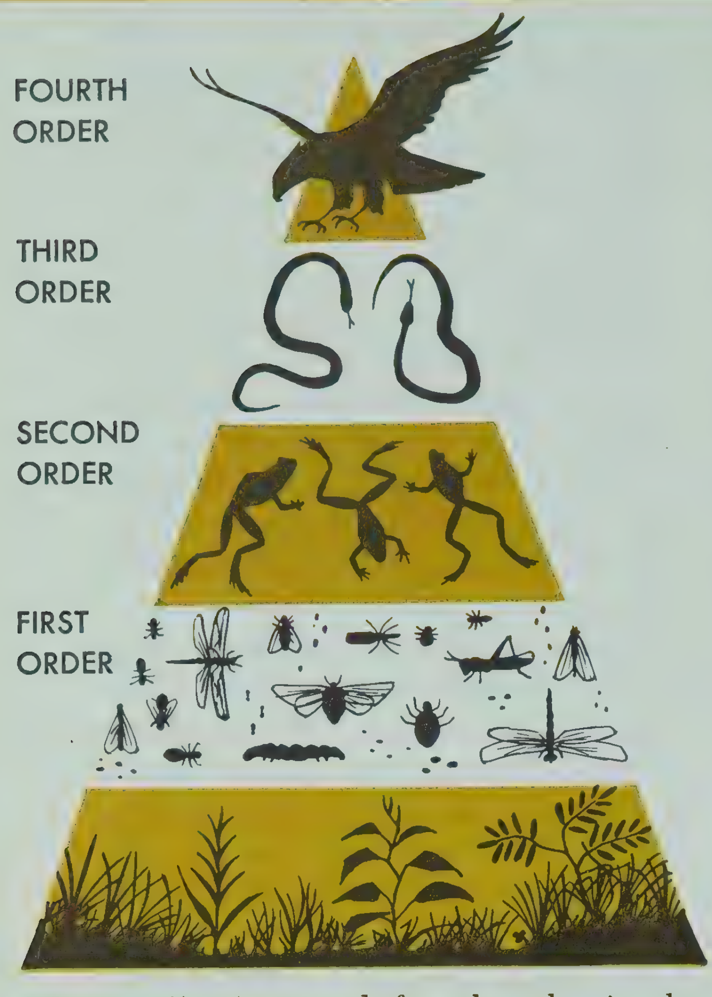
In a biological community, we usually find that the members play distinct roles. If we use a pond community as an example, some members, like the green plants, are *food producers*. Other members are *consumers*. Small animals consume plants, and larger animals may consume smaller animals. So the lives of these organisms are interrelated. And you can see that the larger animals cannot survive unless there are smaller animals for them to eat.

Biologists have learned that the total number of a species in a community is often related to the role it plays. Animals that eat other animals are found in small numbers when compared with animals that eat plants. And animals that eat plants are found in smaller numbers than the plants themselves. Biologists call this a *pyramid of numbers*, as shown in Fig. L–15.

Check your notes to see if you have any evidence of a pyramid of numbers in the community you studied. Make a diagram to represent what you found.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What changes would you expect to observe in a community during the various seasons of the year? Why?
2. Suppose that all members of a given population were removed from a community. What effect do you think this would have?
3. Do you think that members of one community are affected by members



L-15. A pyramid of numbers showing the orders of consumers.

of another nearby community? Explain.

4. What roles do bacteria and fungi play in a freshwater community? What evidences do you have for your answer?

INTERACTION BETWEEN COMMUNITY MEMBERS AND THE ENVIRONMENT What effect do you think sunlight has on a pond community? What will happen to a sample of pond culture if it is placed in darkness for a period of time? Write your prediction in your notebook so that you can refer to it later and see if it was correct.

To find out what actually happens, divide a quantity of pond culture between two battery jars. Place one jar in a dark place at room temperature. Place the second jar in a lighted place at room temperature. Check each sample, every few days, to see if you can observe any changes in the kind and number of organisms present. Make and examine slides of culture samples. Each time you make an observation, record the findings in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What effect does the presence or absence of light seem to have on the plants in the culture? What evidences do you have for your answer?
2. What effect does the presence or absence of light seem to have upon the animals in the culture? What evidences do you have?
3. How accurate was your prediction about the changes that would take place when the pond culture was kept in darkness?
4. The light that you used in this test was no doubt sunlight. What effect do you think colored light would have on the pond cultures? How could you test your ideas?

EFFECTS OF TEMPERATURE CHANGE What about the effect of temperature change upon a pond community? You already have some evidences from the experiment described on page 116. But what will happen to a sample of a community held at refrigerator temperature for some time? Write your prediction in your notebook, so that you can refer to it later.

To test your ideas, divide a quantity of pond culture between two small battery jars. Keep one jar at room temperature and place the other jar in a refrigerator. In order to eliminate light as a factor, you will have to place an opaque cover over the jar that is not in the refrigerator.

Check the two samples, every few days, for a week or two. Record changes in the kind and number of organisms present. If possible, check the bacteria populations also.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What effect does the temperature change appear to have upon the plants? What evidences do you have?
2. What effect does the temperature change seem to have upon the animals? What evidences do you have?
3. How accurate was your prediction about what would happen when the culture was kept in a refrigerator?

EFFECTS CAUSED BY FREEZING Many freshwater communities are subject to freezing temperatures from time to time. In fact, the water of the community may be frozen solid in the winter season. Can any members of such a community survive under these conditions?

To test the effect of freezing upon the small and simple members of a pond community, divide a sample of pond culture between two plastic containers. Place one container in the freezing compartment of a refrigerator. Place the other in a dark place at room temperature. At the end of 24 hours, remove the container from the refrigerator and allow the ice to melt slowly.

After the ice has melted, and the water is at room temperature again, check samples of the culture for the presence of living plants and animals. Be sure to check for protozoa and bacteria. Compare the results from the frozen container with those from the container that has been at room temperature.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What effect does freezing seem to have upon the simpler members of a community? What evidence do you have for your answer?
2. When you checked the melted sample for living things, how were you able to decide if something was alive or not? What other ways could be used to help you decide?

EFFECTS CAUSED BY DRYING It is obvious that most members of a freshwater community are adapted to life in the water. What effect do you think evaporation and drying has on them? What would happen to the small members of a community if the water was allowed to evaporate slowly?

To get some answers, divide a sample of pond culture between two culture bowls. Keep both bowls in a lighted place at room temperature. Let the water evaporate, but keep one bowl filled by adding pond water to make up for the evaporation loss. Check the contents of each bowl, every day or so, for changes in the plant and animal populations. Can you predict the changes which will take place?

ANALYSIS Prepare answers to the following questions in your notebook:

1. What effect did drying have on the populations in the culture? What evidences do you have for your answer?
2. Each year some pond communities dry up, but when rains come these communities revive. Explain.
3. Can bacteria and small fungi survive drying? How could you test your response?

SUMMARY: BLOCK I

The first five chapters of this book have been designed to introduce you to certain concepts about how living things differ from nonliving things, the variety of life forms that exists, and how living things interact with each other and with the factors of their environment. In addition, you have learned about biologists, the way they name and classify organisms, and some of the ways in which they make observations.

Wherever we may be, plants and animals make up a part of our environment. This environment also includes physical things and forces, such as rocks, soils, water, and sunlight. It is an environment that undergoes constant change, from day to day, from season to season, and from year to year. The nature of the environment at any given time determines what kinds of organisms are likely to survive.

The solids, liquids, and gases of our world are different forms of matter. This matter is made up of 92 elements that exist "naturally." Individual units of these elements are known as atoms, and groups of two or more atoms are usually bonded together to form molecules. Molecules are the units of what we call compounds, and most of the substances around us exist as compounds. Some atoms are radioactive, and compounds that contain such atoms are radioactive also.

Plants and animals are composed of cells, and the living substance in these cells is protoplasm. The elements carbon, hydrogen, oxygen, and nitrogen make up the bulk of protoplasm. These elements appear in compounds such as water, carbohydrates, fats, and proteins. Carbohydrates, fats, and proteins are all carbon compounds.

Enzymes are a special group of proteins found in plant and animal cells. Hormones, which sometimes are proteins, also are produced by certain cells. Other special substances in cells are the nucleic acids, known as *DNA* and *RNA*.

Cells require energy so that they can carry on chemical changes and do work. Such food substances as glucose are broken down in the oxidation process to supply energy. The energy is trapped and held by a phosphorus compound called *ADP*, which becomes *ATP* when it is energy-charged. If the energy of an *ATP* molecule is then used to do work, the molecule becomes *ADP* again.

The protoplasm of a cell can, therefore, release and use the energy of certain compounds. It can use this energy to react to stimuli, absorb and digest foods, produce materials needed for growth and repair, discharge waste products, use oxygen, and reproduce. It is the ability to do such things that sets living things apart from the nonliving.

Some organisms are single-celled; others have bodies composed of many cells. Most cells are small, but some are a good deal larger than others. A cell generally has a cytoplasm surrounded by a living cell membrane, and one or more nuclei. Various molecules pass through cell membranes, because these membranes are semipermeable. Green plant cells contain chloroplasts. The chlorophyll in these chloroplasts carries on the food-making process of photosynthesis.

Photosynthesis has two general phases. In the light phase, chlorophyll receives energy from sunlight, and uses this energy in order to split water into hydrogen and oxygen. The oxygen is then set free, but the hydrogen is not. In the dark phase, carbon dioxide and hydrogen are used to produce a series of compounds, and finally simple sugars. Simple sugars are carbohydrates, but plant cells also produce plant oils and proteins. Both sunlight and artificial light will provide energy for photosynthesis.

In the many-celled organisms, similar cells are grouped to form tissues. Cells of tissues, such as muscle tissues, have special functions. Tissues often are arranged together in the form of organs, and organs are in turn associated to form systems. A system performs some general function, such as digestion. The more complex organisms are marked by the presence of organs and systems.

Spirogyra is an alga that grows as a filament of cells. These cells are all more or less alike, although special spore cells are formed in the process of reproduction. *Spirogyra* is a green plant and a food maker. Many other algae are single-celled, but some of them, like the rockweeds, are many-celled and bulky. Bread mold is a fungus, and it does not make foods. Its cells form hyphae that are of several types, and it produces spore cells that can develop into new mold plants.

Moss plants are rather simple types that live in moist places. The moss plant has a branching structure and develops upright stems and small leaves. The stems and leaves are green, and mosses are food makers. In their reproduction, they develop male and female sex cells.

A hydra is a simple, aquatic animal that develops a number of special cells, as well as primitive tissues. It reproduces by budding, and also through the formation of egg cells and sperms.

Earthworms are more complex than hydras. Earthworms are divided into segments, and their bodies contain tissues, organs, and systems. The systems deal with such functions as digestion, blood circulation, responses to stimuli, discharge of wastes, and reproduction.

To avoid confusion, biologists describe a kind of organism as a species, and give the species a scientific name. Similar species form a genus, and similar genera, a family. Families are grouped to form orders, orders to form classes, and classes to form phyla. The existing phyla of plants make up the Plant Kingdom, and the existing phyla of animals make up the Animal Kingdom. Simple "borderline" organisms are placed in the Protist Kingdom.

The individuals of a species are never exactly alike. Rather, there is variation among them. This is even more evident when we compare the members of families, orders, or classes.

The plants and animals you have been reading about live together in communities. In such a community, the members of any one species make up a population. In Block II you will learn how the many populations of a community are related to one another. You will also learn how these populations are affected by changes in their environment.

WORD MEANINGS

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. A solution that is commonly used to preserve the parts of plants and animals is (a) benzol; (b) gentian violet; (c) formalin; (d) eosin.
2. When water molecules pass through a semipermeable membrane, it is a case of (a) conjugation; (b) osmosis; (c) budding; (d) none of the foregoing.
3. In the following list, the substance you would use to stain a cell red is (a) eosin; (b) benzol; (c) alcohol; (d) formalin.
4. When a yeast cell divides, the process is known as (a) fission; (b) conjugation; (c) osmosis; (d) budding.
5. If you found a group of bullfrogs living in and about a pond, you could describe the group as a(n) (a) class; (b) community; (c) population; (d) order.

6. A group of animals of various types, living together near the bottom of a deep trench in the ocean, could be described as a(n) (a) phylum, (b) adaptation, (c) population, (d) community.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Petri dishes are often used in raising cultures of bacteria and fungi.
2. Certain protozoa will feed actively upon bacteria.
3. The element carbon is found in carbohydrates, but is not present in fats and proteins.
4. Before man split the atom, there was no radioactivity in our world.
5. Sugar molecules pass through a semipermeable membrane faster than water molecules do.
6. A paramecium reacts negatively to the presence of eosin in its environment.
7. A paramecium can only divide to produce two cells immediately after it has conjugated.
8. In its process of conjugation, *Spirogyra* forms special spore cells.
9. Green leaves of plants, that are living in sunlight, often contain stored starch.
10. When a green plant is actively making foods, it is likely to discharge excess oxygen.
11. When a leaf is green in appearance, you can be sure that no pigments, other than chlorophyll, are present in it.
12. Yeast cells differ from other cells, because they do not appear to have nuclei.
13. Earthworms obtain oxygen from the air in their burrows, through the use of gills.
14. The central control in an earthworm's body is a nerve chain.
15. You would not ordinarily expect to find bacteria in a pond culture.
16. In a given pond community, you would expect to find more individual algae than fish.
17. The presence or absence of sunlight has little effect upon organisms that live in a pond community.
18. All living things are killed by freezing temperatures.

19. When a pond dries out in midsummer, all of the organisms that lived in it are killed.
20. Various species of plants and animals may appear in more than one type of biological community.

DISCUSSION QUESTIONS

1. Did the result of the test, described on page 116, demonstrate that a temperature of 212° F will kill all living things? Explain.
2. When you put water in a refrigerator tray, it soon freezes and becomes ice. Is this a physical change or a chemical change?
3. Why could you say that it would be remarkable if a Geiger counter showed no radioactivity in your environment?
4. In osmosis, do only small, active molecules pass through a semi-permeable membrane? Give reasons for your answer.
5. Do you think that osmosis is represented in the normal life activities of a cell? Explain your answer.
6. What kinds of organisms seem to be closely associated with decay processes? What do you think our world would be like if these processes did not go on?
7. How are the lives of the algae in a pond related to the lives of small animals that live in the pond?
8. Which of the following would probably be most common in the waters of a pond: turtles, algae, or insects? Why do you think so?
9. If the physical conditions of a pond community were greatly changed, (for example, if the pond became largely filled with mud), would you expect to see changes in the populations? Why?
10. What do you think would happen to a pond community if it received no light for a long period of time? Why do you think so?
11. Year after year some pond communities are frozen solid, yet each spring these communities continue to exist. Can you give any explanation of what happens?
12. If you set up a miniature pond community in a sealed glass jar, and conditions of life in the jar are favorable, do you think that the community can continue to exist for a period of time? Explain.
13. What factors seem to determine the kind of community that will exist in a given area?
14. Do you think that the plant and animal populations in a pond community remain more or less the same throughout the year, or are some of them better represented at one time than at another time?

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BLOCK II

The Natural Community

Men have lived on the earth for many thousands of years. Our ancestors knew such mammals as the woolly mammoth and the saber-toothed tiger. Men survived the rigors of the last great ice age, and about 20,000 years ago, some of them migrated to the Americas.

In the old world, centers of human population developed in Europe, Africa, and Asia. Long after the great glaciers of the ice age had melted away, men were simply food gatherers. They hunted, fished, and sought plant products in the fields and forests. Much later they began to raise certain useful plants and animals, and thus assured themselves of more dependable supplies.

We can be sure that one goal of primitive man was to obtain adequate food materials. They had long depended upon the environment for whatever it had to offer. A giant step toward better things was taken when these ancients began to raise their own food products. This was one of the great breakthroughs of history.

Down through the centuries, men have depended to a greater extent upon cultivated plants and domesticated animals. Meanwhile, they have continued to use various plant and animal products that nature provides. In both cases, many communities have been over-exploited. Soils have lost their fertility. Water supplies have been exhausted. Various types of wildlife have become scarce or nonexistent.

It is only in recent times that we have learned the meaning of conservation. When we practice conservation, we use resources wisely, so that they are not destroyed, and new supplies of materials are produced year after year. To do this effectively, we must understand how plants, animals, and nonliving factors interact in the natural community. This is the subject of Block II.

CHAPTER 6

Food Resources

In order to survive, organisms must have food and must avoid being eaten. It is the problem of food getting that concerns us in this chapter, and as far as organisms are concerned, it is "half the battle."

The *food makers,* of course, can supply themselves with foods, provided they are in favorable environments. The *consumers,* which include all of the animals, must find their foods ready-made. When food is abundant, it does not figure largely in survival. But when consumers are numerous and food is scarce, the situation is very different. Competition for available food is bound to be severe, and organisms react in various ways, as we shall see.

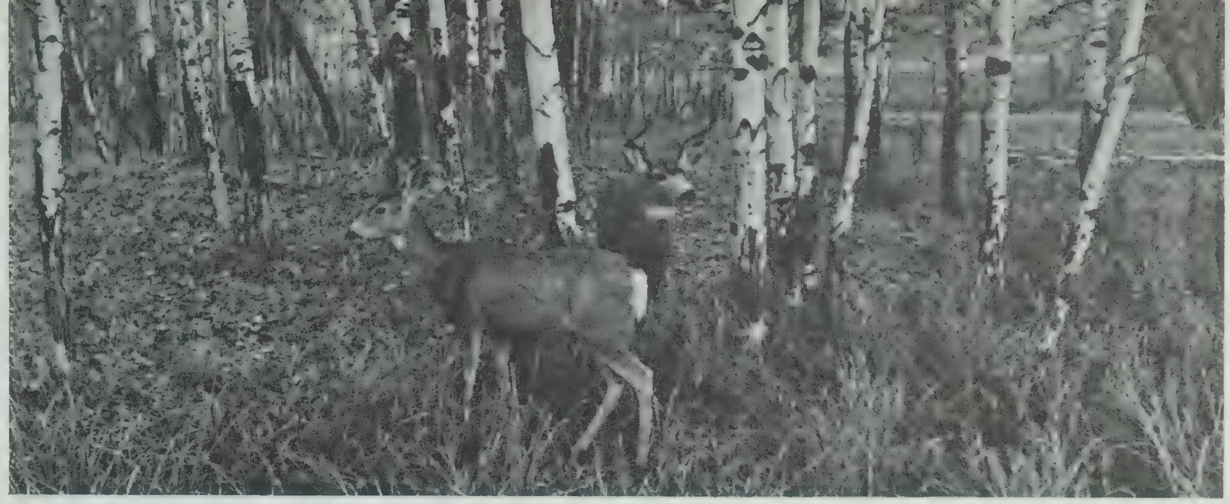
COMMUNITY FOOD SUPPLIES

In Block I, you learned a number of things about communities. For example, you found that plants and animals may live together in a pond community, and that you can set up a small, artificial community by putting some aquatic plants and animals in a battery jar of pond water.

Communities—large and small. You can also think of communities in a larger sense. The inhabitants of a vast tract of grassland may make up a single prairie community. The plants and animals living in a large, forested area may be described as members of a forest community. In the same way, you find communities in the deep sea, in the shallow water of coastal bays, and far above sea level in mountain valleys.

In some cases, the boundaries of communities are well-marked. Plants and animals that live on a small island in mid-ocean make up a land community that is clearly separated from all other land communities. But in other cases, boundaries are not so evident, and communities tend to merge with one another.

There are, of course, some populations that are likely to be found in a number of different communities. For instance, wherever you find living



6–1. The deer in this picture are consumers. They must be able to find their own food. (*U.S. Forest Service*)

6–2. How many communities can you identify in this picture? (*U.S. Department of the Interior, Bureau of Land Management*)

6–3. A freshwater stream community. (*Walter Dawn*)

6–4. What type of community is this? (*Hays from Monkmeyer*)

6–5. An expanse of water forms a natural barrier, preventing some organisms from moving from island to island. (*Monkmeyer Press Photo Service*)

things, you are likely to discover that bacteria, fungi, and protozoa are present. Some of these simple forms of life are highly adaptive. That is, they can survive under a variety of different conditions.

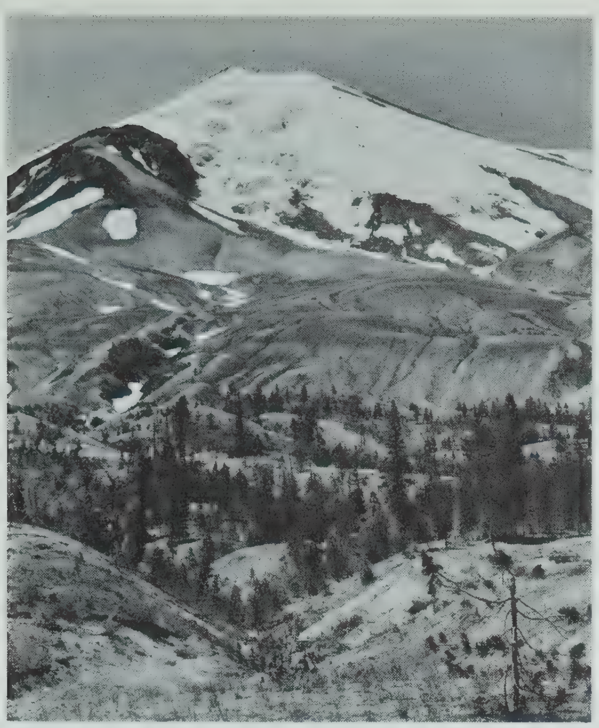
Natural barriers. On the other hand, many plants and animals are so-adapted that they can only live under certain conditions. For them, a given area may be too cold or too warm. There may be either too much or too little water. The soil may or may not contain the right chemical substances. If they are green plants, there may not be enough sunlight for successful growth. If they live in the sea, pressure may be a limiting factor.

You see, there are *natural barriers* that limit the areas in which many organisms can survive. A fish, adapted to life in shallow water, would be quickly killed by the terrific pressures that exist in the deep sea. The internal organs of some deep sea fish, that have been brought to the surface, burst open because of the sudden change in pressure. The fish that is hauled out of the water soon dies because its gills are not able to obtain oxygen from the air.

Similarly, as you climb the side of a high mountain, you reach a point near the top called the ***tree line.*** Above this point there are no trees. Only the plants that are adapted to very cold conditions can survive above the tree line.

So there are many physical factors that limit the kinds of communities in which certain plants and animals exist. Also, there are barriers that keep various plants and animals out of communities, where they might otherwise be. A wide expanse of sea, for instance, may keep many organisms that live on one island from reaching another island that is equally habitable.

Food as a factor. Food also is a very important factor in determining whether or not organisms can live successfully in a given area. A food-making plant must have conditions suitable for its growth. If this plant and



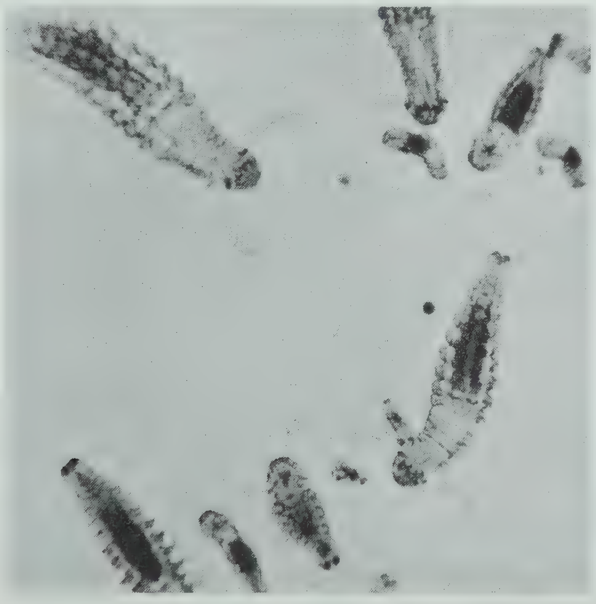
6–6. Can you see where the tree line begins in this picture? (*U.S. Forest Service*)

others like it are able to make a good deal of basic food, the community can support a large animal population. You are likely to find large animal populations wherever food is abundant.

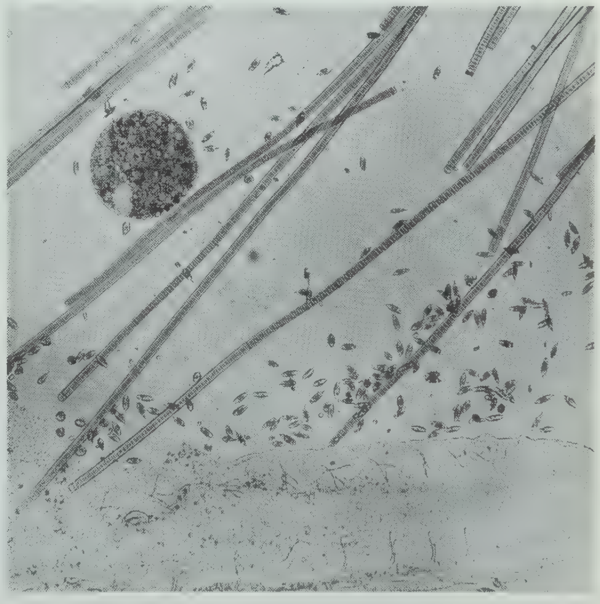
In the sea, it is the *algae* that are largely responsible for basic food making. Most of these algae are small, single-celled types that float at or near the surface. Together with simple, floating types of animal life, they make up what is known as ***plankton*** (*plank*-tun). Plankton is well represented in the oceans, and is sometimes found far from land, and in the colder waters.

In freshwater ponds, lakes, and streams, the story is much the same. The most important basic food makers are the simple little algae, although higher plants growing in the shallow waters make a contribution. Plankton is represented here too, floating at or near the surface. To a large extent, the amount of plankton determines the size of the animal population.

On land, conditions are somewhat different. Here the more important food makers are the higher plants, and to a large extent, this means seed plants. But again, the extent to which these plants produce basic foods determines the number of consumers the area can sup-



6–7. Zooplankton, the larvae of a simple, aquatic organism found in plankton. (*Walter Dawn*)



6–8. Plankton, the main food source of aquatic communities. What is plankton composed of? (*Walter Dawn*)

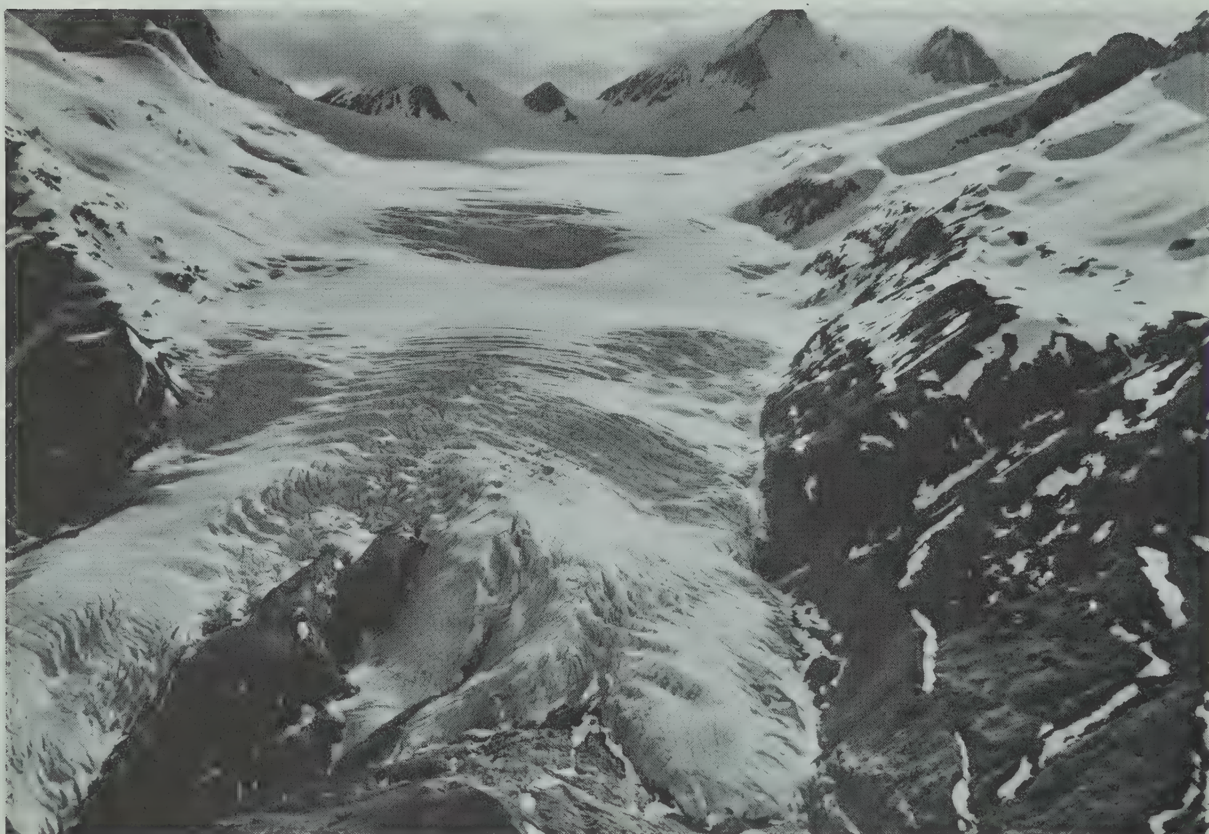
port. Even in a semi-desert area you find some plants, but they are likely to be few and far between. As a result, such an area can support only a limited number of plant eaters.

VARIATION IN FOOD SUPPLIES

The record of the rocks makes it clear that conditions on our earth have changed a great deal during the past. Many places, where land communities exist today, were once under the sea. Some areas of the present sea bottom once rose above the waves. Climates also have changed during the millions of years the earth has existed. At various times in the past, the area where you now live has been much warmer, and at other times much colder.

The last great ice age. There have been rather cold periods in the earth's history, when ice sheets moved down from the north to cover much of North America, Asia, and Europe. These ice sheets or glaciers destroyed the food-making plants in their paths. Most of the animals that survived were driven southward by the slowly advancing ice.

When warmer times came again, the glaciers retreated. The last time this happened was about 50,000 years ago. As the ice melted away from the land, green plants could grow once more, and with them came new generations of animals. Man existed during the last great ice age; in fact, fossils of human types date back nearly two million years. After the end of this ice age, men reached North and South America, and



6–9. A glacier, like the one shown here, was once responsible for destroying many species of plants and animals. (*Mac's Foto Service, Anchorage, Alaska*)

6–10. This prehistoric skull, *Zinjanthropus,* is approximately 1,750,000 years old. Parts of the skull were discovered in Tanganyika in 1959. (*National Geographic Society*)

established the ancient American lands that existed before the coming of the European explorers.

Since climate must be favorable for the development of many food-making plants, and since climate is subject to change, food production in a given area is not likely to be the same year after year and century after century. But the changes we are discussing are not likely to be rapid changes.

The effect of the seasons. Everyone knows that harvest time is a time of plenty. The plants that began to grow in the first warm days of spring have matured. They have produced roots, stems, leaves, fruits, and seeds, which provide ample foods for consumers of the land community. During the warm summer months, the consumer population has also expanded. Increasing numbers of consumers have been able to find foods, because green plant production has increased.

Then the frosts of autumn usher in a change. Many plants are killed by the oncoming cold, and the activity of other plants slows down. Many of the smaller animals die, and others go into various retreats for the duration of the winter season. Some birds depart for their winter homes in the south. When the snows come, the active, consumer population is greatly reduced. You might say that this results from an effort to escape winter weather, but this is only part of the story. The fact is that the community cannot *support* as many active consumers as it did during the growing season. As a result, certain populations become reduced in numbers.

This section can be summed up by saying that a given land community has a certain food-producing ability or *po-*

6–11. A young white-tail deer starving in winter. (*Rue from Annan Photo Features*)

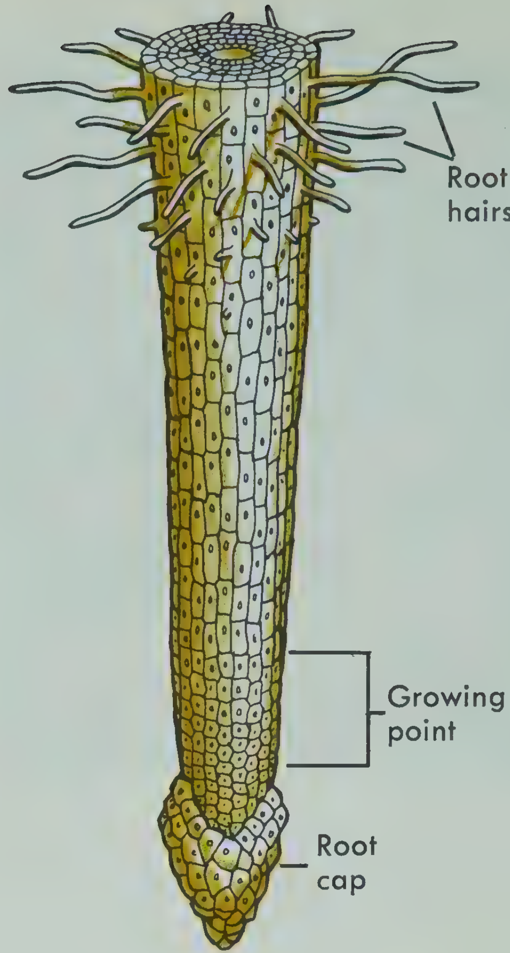
tential. Basically, this potential depends upon such factors as climate, weather, soil, and sunlight. But even so, the potential varies with the seasons. It is high during the growing season, and populations expand accordingly. It is low during the winter season, when active populations become greatly reduced.

FOOD MAKERS OF LAND AREAS

Let us now turn our attention to food making by land plants. The species of greatest importance are the various types of seed plants. These plants have vascular tissues, and they develop roots, stems, and leaves. All of these structures play an important part in the process of food making. For example, vascular tissues carry water and minerals from the roots to the leaves. They also carry food from the leaves to other parts of the plant.

Roots of seed plants. The roots of seed plants vary a good deal. Some root systems spread out beneath the soil surface. Others go down deeply into the soil. Some plants have finely branched root systems. Others, such as the beets, carrots, and turnips, develop large, fleshy roots. Generally, all of these roots have similar functions. They anchor the plants in place, and absorb the water necessary for photosynthesis from the soil. Mineral compounds, essential to plant growth, are dissolved in this water. Some roots also serve as important storage centers for foods.

Figure 6–12 is a diagram that shows a young, growing root. The ***growing point*** is the area where cells are dividing rapidly and the root is increasing in length. At the tip of the root is the ***root cap***, which is a rather loosely packed mass of cells. Root cap cells are scraped off as the root tip pushes its way down into the soil. Just above the growing point many of the surface cells bear slender processes known as ***root hairs.*** These root hairs serve to absorb water and dissolved mineral compounds from the soil.



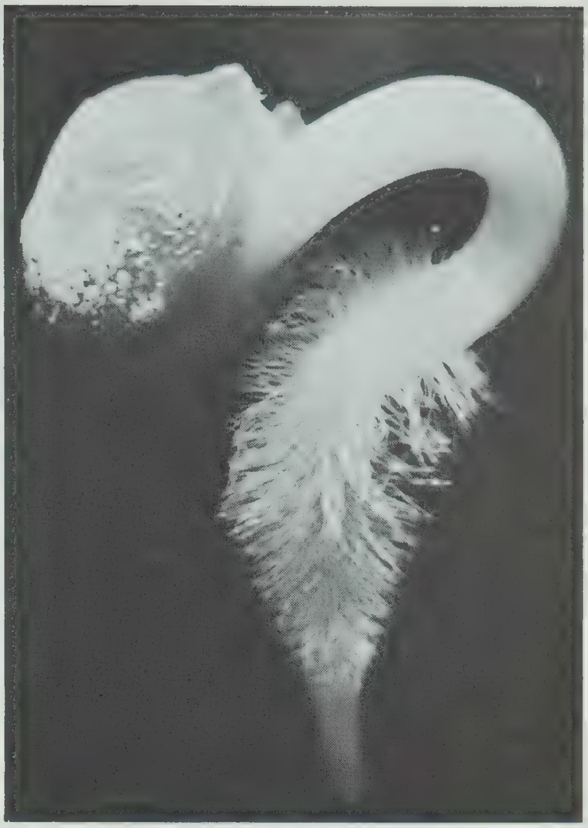
6–12. Diagram of a young, growing root.

Water absorbed by a root is passed from cell to cell until it reaches duct cells in the central core of the root. The liquid now goes upward through these duct cells, and later through duct cells of the stem, until it reaches the leaves. Cells of other ducts convey foods made by the leaves to the stems and roots.

The ducts are made up of vascular tissue cells of two different types. One vascular tissue is made up of heavy

walled cells. It is called ***xylem*** (*zy*-lem), and this tissue carries water and dissolved minerals. The other vascular tissue has cells with thinner walls. It is called ***phloem*** (*flow*-em) tissue. Phloem tissue carries foods that have been made by the plant. Ducts composed of xylem and phloem tissues are found in roots, stems, and leaves.

If a group of cells are to act as a duct or transportation pathway, liquids must pass from cell to cell. This, of course, is exactly what happens. Molecules of the liquids pass through cell membranes and cell walls in going from one cell to another cell. The passage of water molecules through the cell membranes is the process of osmosis that was described on page 119.



6–13. A young radish seedling with many root hairs. (*Hugh Spencer*)

OBSERVING ROOT HAIRS

Each root hair is a part of the *cytoplasm* of a root cell that has pushed outward to form a threadlike process. You can study the arrangement of root hairs by sprouting some radish seeds. Young radish roots have long, slender root hairs.

ROOT HAIRS ON YOUNG RADISH PLANTS Put a layer of cotton in the bottom of a shallow pan, and add water from time to time to keep the cotton layer moist. Sprinkle some radish seeds on the wet cotton surface, and then wait until the seeds have sprouted and the young roots are about an inch long. You can now see a mass of slender, white structures a short distance above the root tip. These are the root hairs.

Using a fine-pointed scissors, cut off a half inch of a young root that bears root hairs. Pick the piece up with a forceps and put it in a drop of water on a blank slide. Cover your specimen with a cover glass. Now observe it carefully under the low power of a microscope or a projector.

ANALYSIS After completing the observation of root hairs, prepare answers to the following questions in your notebook:

1. On what part of the young root were the root hairs most numerous?
2. Do you think the membrane that surrounds a root hair is important? Give your reasons.
3. Would you consider root hairs to be tissues? Why?

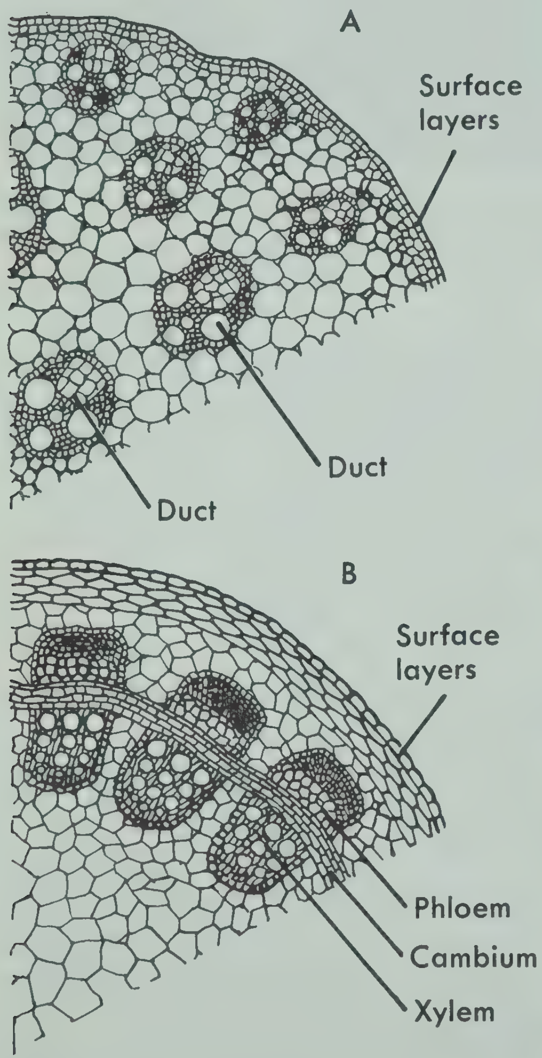
Seed plant stems. Stems of seed plants serve a number of functions. In many species, they hold the leaves up where they will be in contact with sunlight. But in some plants, such as the cactus plants, the stems are the main food-making centers.

In our garden and field plants, however, leaves are the important food factories. The stems provide pathways through which materials pass from roots to leaves, and from leaves to roots. Foods also are stored in various stems.

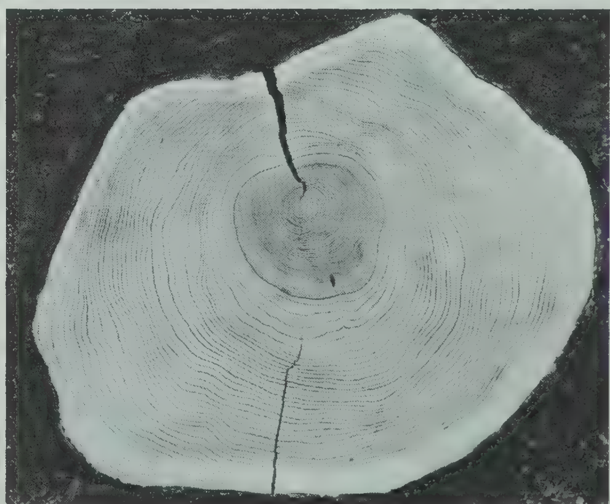
Structures of plant stems. Like roots, the stems of seed plants vary in structure. Cross sections of two types of seed plant stems are shown in Fig. 6–14. In *A* of Fig. 6–14, you see that the bundles of ducts are scattered here and there within the stem.

In *B* of Fig. 6–14, however, you find a more orderly arrangement of the ducts. Here the ducts form a sort of broken ring, not far from the surface of the stem. They are located on either side of an actively growing layer called the ***cambium*** (*kam*-bee-um) layer. Common bean and tomato plants have the type of stem in which a cambium layer lies between the phloem ducts and the xylem ducts.

The important thing to remember about a cambium layer is that it can keep on forming new cells. In other words, it continues to grow. In the case of a tree, this is vital. A bean plant has a *fleshy stem,* and it completes its life span in a single season. But a tree has a *woody stem* that we call the tree trunk. On the outside of the trunk is the bark. The inner layer of the bark is phloem tissue. Just inside it is the cambium layer, and then layer after layer of xylem.



6–14. Describe the differences that you see in these two cross-sectional drawings of plant stems.



6–15. How would you determine the age of this California redwood tree? (*Georgia-Pacific Corp., AFPI Photo*)

Every year in the life of the tree, the cambium forms new xylem tissue on its inner side. Thus, the cambium is pushed outward, and the phloem and bark are also pushed outward. New phloem and bark cells are formed. The tree trunk becomes thicker.

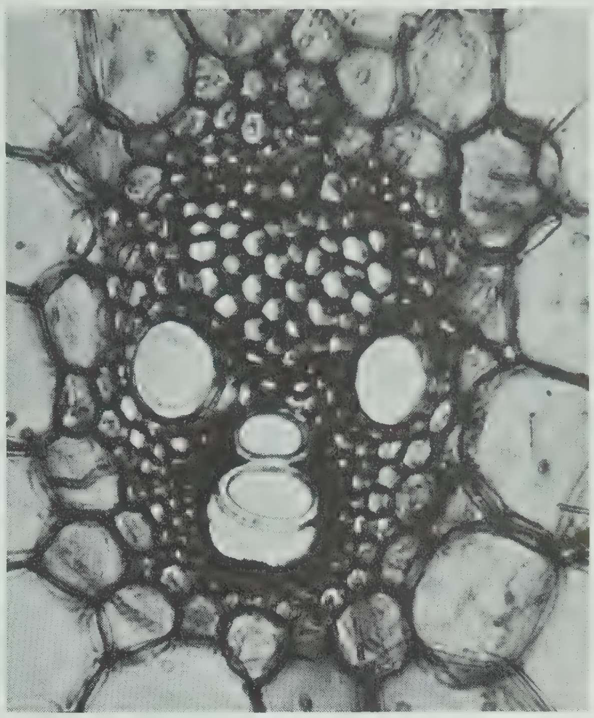
When you cut through a tree trunk, you find ring after ring of what were once active xylem cells. These rings of xylem are the *growth rings* that you count when you want to know the age of the tree. Usually one growth ring is formed each year. Only the xylem cells near the cambium layer are still active. But the cell walls of the old xylem tissue remain to form the *wood* of the tree trunk.

STEM TYPES

To observe the structures of the two stem types found among flowering plants, you can study the cross sections of (a) a young corn stem, and (b) a young bean, sunflower, or maple stem. You can use prepared slides, if they are at hand, or you can make temporary mounts of corn and bean cross sections, as described on page 114.

Examine your slides under the low power of a microscope or a projector. You will see that one of them has the ducts arranged as in Fig. 6–14*A*, and the other has the ducts as in Fig. 6–14*B*.

The type of stem that has a cambium layer is the type found in many of our vegetables, flowers, and shade trees. Some of them have fleshy stems like bean or tomato plants, and others have woody stems like the trees.

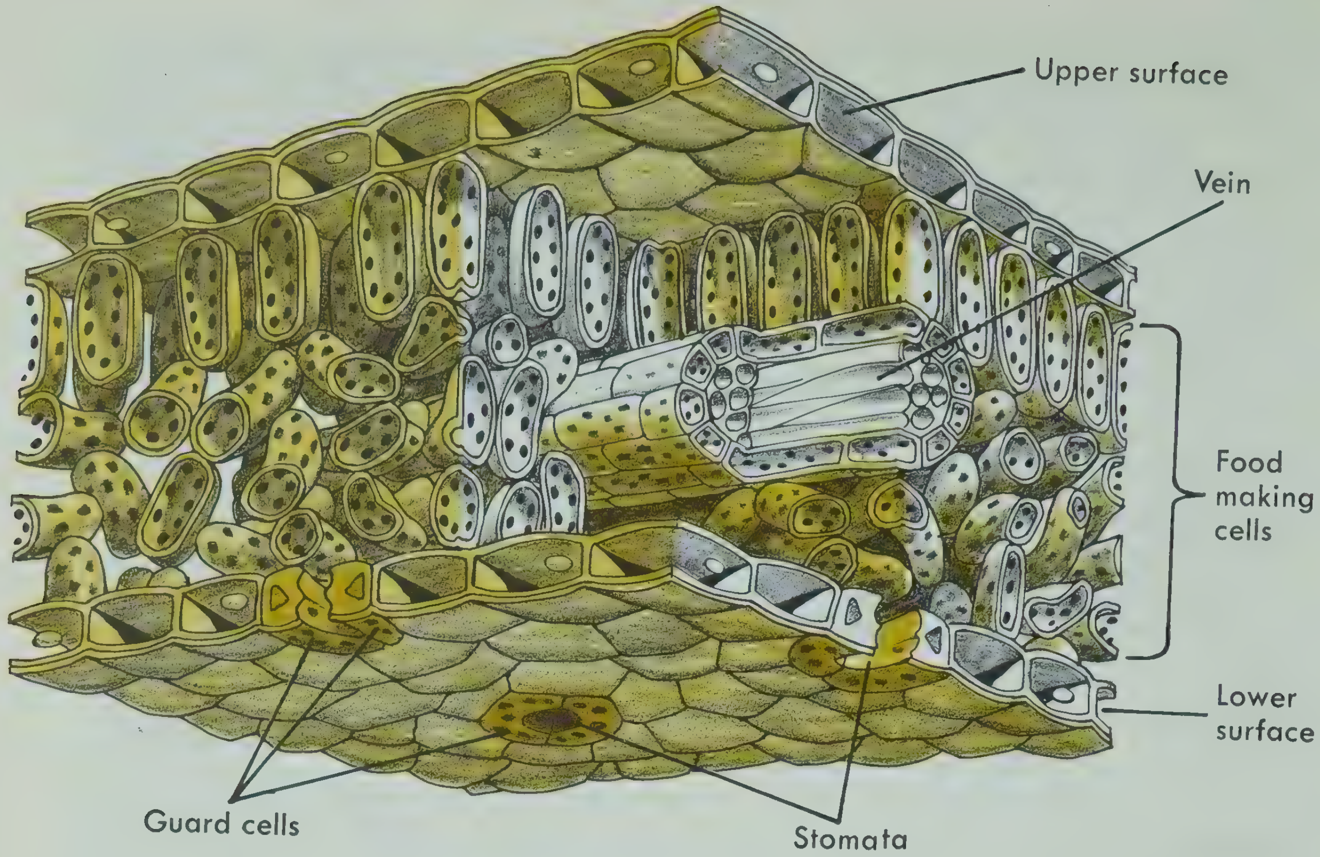


6–16. Cells that form a duct in a corn stem. (*Russ Kinne from Photo Researchers*)

ANALYSIS After completing your observation of the stem structures, prepare answers to the following questions in your notebook:

1. Which cross section, that you examined, had the ducts arranged as in Fig. 6–14*A*? Fig. 6–14*B*? To which type did the celery stem you studied on page 100 belong?
2. In the type of stem that develops a cambium layer, which ducts convey water from the roots to the leaves? Food from the leaves to the roots?
3. Once the type of stem shown in Fig. 6–14*A* has become mature, do you think it could continue to grow in thickness? Give a reason for your answer.

Seed plant leaves. The leaves of seed plants vary a good deal in size and shape. But in most species, their struc-



6–17. A cross section of a leaf.

tures perform similar functions. These functions are largely concerned with food making.

A cross section of a leaf reveals a number of important features. Such a cross section is shown in Fig. 6–17. The veins of the leaf, which you can see from the outside, are bundles of ducts composed of phloem and xylem tissue. These ducts transport water and foods. A layer of cells that does not contain chlorophyll forms both the upper and lower surface of a leaf. Naturally, these cells cannot make foods. Here and there the surface layers have tiny openings in them that are called ***stomata*** (stow-*mah*-tuh). In some species of plants, most of the stomata are on the lower surface of a leaf, in some the stomata are largely on the upper surface, and in others there are numbers of stomata on both surfaces. The presence of these stomata makes it possible for gases to enter and leave the tissues of a leaf. But do not get the idea that a leaf "breathes."

Water and carbon dioxide are the substances from which simple sugars are made. The water is absorbed by the roots, and passes through the stem ducts and leaf veins to the leaf cells. Carbon dioxide enters through the stomata. The stomata also permit the escape of excess oxygen and water vapor.

The cells of the mid-portion of a leaf are filled with chloroplasts that contain chlorophyll. As you have learned, when chlorophyll receives energy from sunlight, it is able to make basic foods. Light and dark phases of photosynthesis are carried out. (See page 51.) The product of photosynthesis is simple sugars, but green leaves also produce plant oils and proteins.

LEAF TYPES AND STRUCTURES

COMPARING THE STRUCTURES OF LEAVES Leaves vary in size, form, and structure. Select three or four different kinds of leaves to study in detail. It might be interesting to compare leaves from plants that normally grow in different kinds of environments, such as dry places, moist places, and very wet places. Observe each of the leaves carefully. In your notebook list what you have observed about them. Be sure to include such things as size, shape, color, surface texture, and vein pattern. The vein pattern can be seen best by holding the leaf up in front of a bright light.

ANALYSIS After making this observation of leaves, prepare answers to the following questions in your notebook:

1. What do the leaves you observed have in common?
2. In what ways are the leaves different?
3. What is it about the shape of leaves that makes it possible for light to reach each cell?
4. Do you think that carbon dioxide gas reaches leaf cells through the upper surface of the leaf, or through the lower surface? What evidence do you have for your answer?

OBSERVING THE STOMATA OF GREEN LEAVES As you have read, leaves have openings on their surfaces called stomata. *Guard cells* (see Fig. 6–17) on either side of a stoma regulate the size of the opening. In this part of your study you will observe stomata, and calculate the number of openings on the lower surfaces of certain leaves.

Select several leaves from different kinds of plants. Prepare temporary slides of specimens in the following manner. Tear a leaf at an angle. You should now be able to see tiny portions of the colorless lower leaf surface along the tear. Cut a tiny piece of this colorless layer off, and place it in a drop of water on a blank slide. Cover the specimen with a cover glass, and mark the slide so you will know what kind of leaf it represents.

Observe one of your temporary slides under the low power of a microscope. When you have located a stoma, center it in the field, and then change to high power. Make a sketch in your notebook to show the shape of the stoma and its guard cells. Include a few of the surrounding cells in this sketch. Repeat the procedure with two or three other leaf types.

Using the same slides, count the number of stomata in a low-power field of view. Move the slide, and count the number of stomata in a second low-power field, and then in a third. Calculate the average number of stomata per low-power field for this specimen. Study your other specimens in a similar manner, and record your observations and calculations in your notebook.

ANALYSIS After making the foregoing observations of stomata, prepare answers to the following questions in your notebook:

1. How is a stoma related to its guard cells? In what ways are guard cells different from the surrounding cells?
2. If you had made slides of the upper, colorless layers of leaves, might you have found stomata in these speci-

mens also? Give reasons for your answer.
3. Did you note any relationship between the number of stomata on a specimen, and the type of environment in which the plant grows? Explain.
4. What was the purpose of moving the slide and making three counts of the stomata in a low-power field?

CARBON DIOXIDE AND PHOTOSYNTHESIS

You have learned that land plants obtain the carbon dioxide used in food making from the air. Since a typical leaf has two flat surfaces in contact with the air, we might assume that carbon dioxide enters the leaf through these surfaces. But does the gas enter equally through both surfaces, or does it enter more through one than the other? We can gather some data that relates to this question by doing the following experiment.

PREPARING FOR THE TEST Place a potted plant in darkness for two or three days. During this time, it is expected that the plant will use up much of the starch it has stored in its leaves. We can prevent gases from moving in or out of a leaf by coating its surfaces with a thin layer of petroleum jelly. Select four leaves of your plant that appear to be about equal in size. Coat both surfaces of one leaf with petroleum jelly, coat only the top surface of a second leaf, coat only the under surface of a third leaf, and leave the fourth leaf uncoated. Label each leaf so that you can be sure how it was treated.

TESTING THE LEAVES Now place the plant in sunlight for two or three days. Then remove the four leaves from the plant. Rub off as much of the petroleum jelly as possible. Test each leaf for the presence of starch, using the method described on page 122.

ANALYSIS After you have completed the foregoing experiment, prepare answers to the following questions in your notebook:
1. Why would a leaf that had no supply of carbon dioxide fail to make foods?
2. Did the amount of starch in your experimental leaves vary? If so, in what manner? How do you explain the results?
3. Might the same experiment with another type of plant leaf give different results? Explain.

PLANTS, ANIMALS, AND OXYGEN

In your earlier studies, you learned that most cells must have oxygen. They use the oxygen to oxidize food molecules. In this process, energy is set free and used to carry on chemical changes within the cells.

Plant cells and animal cells. Are animal cells the only cells that need oxygen? No indeed, for plant cells also oxidize food molecules. But a green plant produces free oxygen as a by-product of its food making. When the plant is making food actively, it dis-

charges surplus oxygen. But the plant cell also uses oxygen in its oxidation or respiration process.

The animal cell has no food-making process. It must obtain its oxygen supplies from outside sources. It discharges carbon dioxide waste in its respiration process. This carbon dioxide can be used by green plants as a food-making material. Meanwhile, green plants set free some oxygen, which can be used by animal cells.

WORD MEANINGS

On a sheet of paper in your notebook, copy the list of words in the first column. Write in the statement from the second column that goes best with each of these words.

1. algae	Most common food-making plants in the sea.
2. communities	Organisms that must find their food.
3. consumers	Populations of organisms living together.
4. leaves	Tiny floating plants and animals.
5. plankton organisms	Most important food makers on land.
6. seed plants	The food-making centers of most common plants.

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. The growing layer of cells found in certain kinds of stems is called (a) duct cells; (b) guard cells; (c) cytoplasm; (d) cambium.
2. Food-conducting tissue is called (a) xylem; (b) cambium; (c) phloem; (d) guard cells.
3. Water-conducting tissue is called (a) xylem; (b) cambium; (c) phloem; (d) guard cells.
4. The openings in plant leaves through which gases enter are called (a) duct cells; (b) stomata; (c) cambium; (d) annual rings.
5. Parts that regulate the size of the openings of leaf surfaces are called (a) stomata; (b) guard cells; (c) natural barriers; (d) growing points.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the

statement. State briefly how you would reword each false statement to make it true.

1. Animals are consumers rather than food producers.
2. As the number of consumers increases, food supplies generally decrease.
3. The boundaries of natural communities are almost always well marked.
4. Higher, more complex forms of life are more likely to be found surviving under a variety of different conditions than are the simpler, less complex forms.
5. Pressure is an example of a natural barrier in the sea.
6. No plants exist in high mountains above the level called the tree line.
7. The most common forms of algae in the sea are the giant kelps that are often hundreds of feet in length.
8. Plankton is found in the sea, but not in freshwater ponds and lakes.
9. The rock record tells us that the coast line of North America has remained largely unchanged since the beginning of time.
10. The last ice age ended about 50,000 years ago.
11. It is thought that no men lived during the last ice age.
12. The food-producing ability of a given land community changes from season to season.
13. The plant parts that we recognize as beets, carrots, and turnips are roots.
14. The part of a root responsible for growth in length is located near the root tip.
15. A root hair is made up of many cells.
16. Stems function as food-producing centers in some plants.
17. The woody part of a tree trunk is made up of water conducting tissue.
18. The layers of cells that form the upper and lower surfaces of leaves are the primary chlorophyll bearing layers.
19. Gases enter and leave the tissues of a leaf through the duct cells.
20. Guard cells regulate the size of the openings in leaf surfaces.

DISCUSSION QUESTIONS

1. In what ways does the quantity of food available in a natural community affect the survival of living things?
2. What kinds of organisms do you think would be found in a prairie community, a forest community, a deep sea community, and a coastal bay community?
3. Why is it that the boundaries between natural communities are often poorly defined?

4. Why is it that bacteria, fungi, and protozoans are among the organisms present in almost every community?
5. On the other hand, why is it that certain kinds of organisms are largely restricted to one particular community?
6. Define what is meant by a "limiting factor." Give examples.
7. In what ways can natural barriers limit the areas in which certain organisms can live?
8. The largest forms of life in the sea feed on plankton rather than on other large plants or animals. How would you explain this?
9. What evidence is there to indicate that conditions on earth have changed a great deal in past times?
10. In what ways can the climate affect the number of plants and animals that exist in a community?
11. In what ways do organisms adjust to changes in climate?
12. What parts of a plant are involved in food making? In what ways is each part involved?
13. Distinguish between the functions of the root cap and a root hair.
14. Describe the functions of a stem.
15. Explain how annual rings are formed.
16. In what ways is the structure of a green leaf related to its functions?
17. Explain what is meant by the statement, "All life is dependent upon green plants."
18. Would you expect desert plants with leaves to have greater or fewer numbers of stomata than plants growing in moist regions? Why?

THINGS TO DO

1. Prepare a bulletin board display using pictures or sketches to illustrate a natural community that occurs near your school. Try to show how the community changes from summer to winter.
2. Using battery jars or aquaria, set up examples of as many types of communities as possible. If actual specimens are not available, you may wish to use toy or clay models as substitutes.
3. If a plankton net or a very fine mesh net is available, pull it through the open water of some nearby pond, lake, or stream. Prepare microscope slides of the material collected in the net and observe with low power. Sketch and identify as many organisms as possible.
4. Using reference books, find out what you can about the possibility of using algae and plankton from the sea as human food. Report your findings to the class.
5. Prepare maps showing the extent of the ice sheets in North America during the ice age.

6. Prepare maps to show how much of North America has been covered by ocean waters in the past.
7. Using a saw, cut thin sections of woody stems. Smooth your sections with fine sand paper and study the pattern of annual rings. Compare sections of as many different kinds of plants as possible.
8. Using reference books, find out what you can about the mechanism by which guard cells open and close stomata in leaves. Report your findings to the class.

READING FURTHER

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CHAPTER 7

Community Relationships

Life in a biological community is a complex and changing experience. Populations vary constantly, as do the physical conditions. Even the hills wear away, as running water carries soil down into the valleys.

One of the things that makes life so complex is the continuing need to obtain food. Left without ants, the anteaters go hungry, and so it is with many other organisms. It is not just a simple case of plants making foods and animals eating plants. Rather, many consumers are adapted to feed upon certain things. Lacking these things, they cannot survive. And so, from the standpoint of food alone, the lives of many organisms are closely interrelated.

THE FOOD GROUPS

By this time, the food makers of a community are well known to you. They include the plants that carry on photosynthesis. They may also include simple organisms that carry on chemosynthesis. The basic foods that they make provide for the existence of the food consumers.

The plant eaters. The food consumers are divided among several food groups. First, there are plant eaters or ***herbivores*** (*her*-buh-vors). They are animals that feed largely or wholly on plant substances. Generally, they consume rather large amounts of food, because pound for pound, plant materials are not as nourishing as animal tissues.

A number of our domesticated animals are herbivores, including cattle, horses, and sheep. Such animals are therefore not in direct competition with man for food. Among wild animals, you find such plant-eating types as rabbits, squirrels, woodchucks, and deer. There also are many smaller animals, including thousands of insect types, that are largely plant eaters.

The flesh eaters. A second group of animals is made up of the flesh eaters or ***carnivores*** (*kahr*-nuh-vors). No doubt you will think of tigers and lions at this

7–1. To which food group do these sheep belong? (*Grant Heilman*)

7–2. Daphnia, a herbivorous, aquatic organism. (*Walter Dawn*)

point, and you are quite right in so doing. Such animals are carnivorous. So are our native foxes, mink, and various other types of mammals.

But carnivores are not limited to the larger types of life that roam the land. Among the carnivores, you find certain single-celled animals, worms, mollusks, insects, fish, and amphibians. To survive, all of these flesh-eating species must have other animals that they can capture and devour.

Animals that eat many things. We come now to a group that includes man himself. Some other members are the pigs, house mice, and house rats. Animals belonging to this group eat a wide variety of foods, that come from both plant and animal sources. They are called ***omnivores*** (*om*-nuh-vors).

A house rat, for example, will eat the flesh of almost any animal. True, it may not kill many other animals, but it will feast on their remains, if it gets the

7–3. The vulture is a carnivorous bird. (*Eric Hosking*)

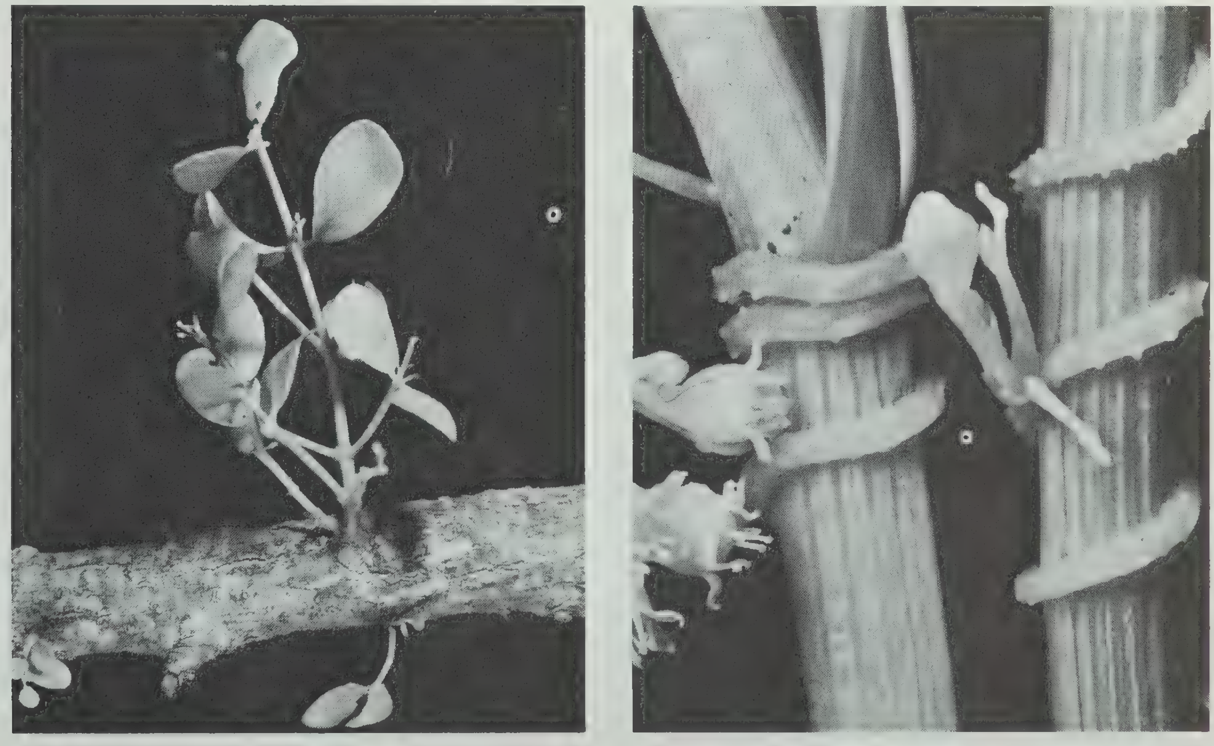
chance. The same house rat also sub sists on all sorts of plant products, including leaves, roots, stems, fruits, and grains.

Being an omnivore has definite advantages. Consider, for instance, the plight of an animal that must have a particular type of food, that is in scanty supply. The omnivore faces no such problem. If just about any plant or animal materials are to be had, the omnivore can survive.

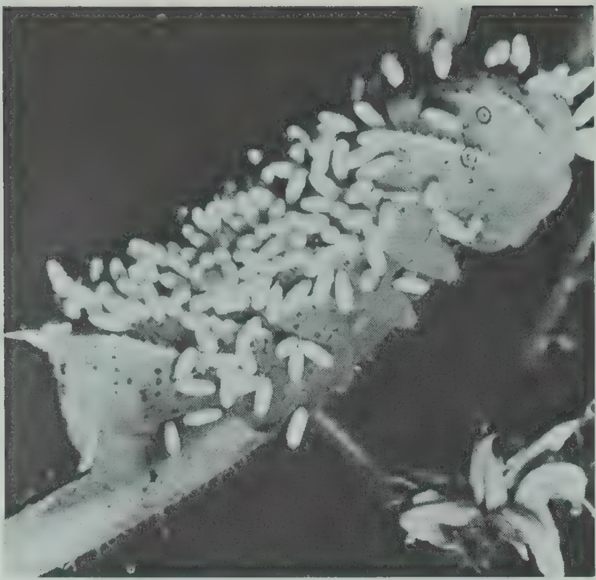
7–4. The black peccary is an omnivorous animal commonly found in South America. (*Walter Dawn*)

The parasites. The *parasites* (*pahr-uh-sytes*) include both plant and animal species. They are the organisms that live at the expense of other plants and animals. Many of them are very small, including various bacteria, protozoa, and fungi. But larger organisms, such as certain worms, insects, fish, and even some higher plants, are also parasitic in one way or another.

A parasite feeds on the tissues or food supply of its victim or *host* and gives nothing in return. It may not kill its host, but it does the host no good. For example, when you have a sore throat, you probably are being attacked by bacteria that are parasites. You sur-



7–5. Two parasitic plants. Left, mistletoe growing on a tree; right, dodder vine attached to plants. (*Dr. Ross E. Hutchins, State College, Miss.*)



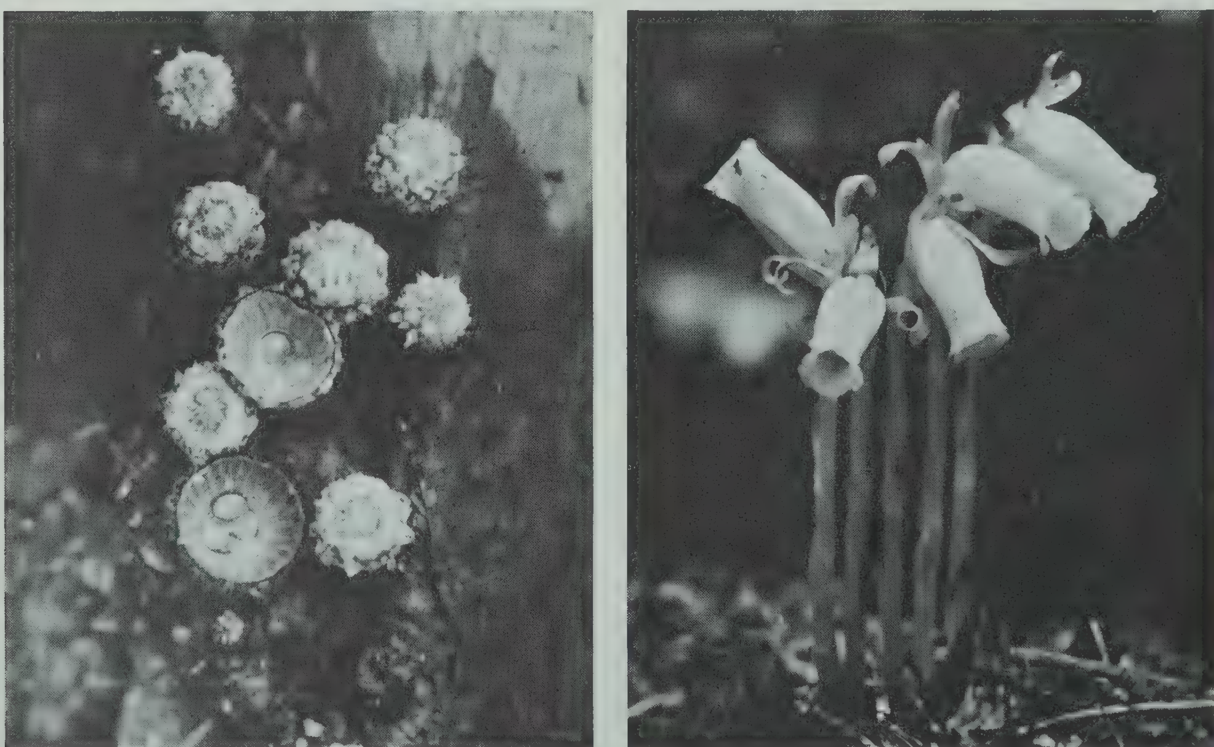
7–6. The larvae from these wasp eggs have a parasitic relationship with the tomato hornworm. (*Walter Dawn*)

vive the attack in time, but it is not a pleasant experience. There are many kinds of parasites in our world. They attack not only man, but other animals and plants as well.

Eaters of dead plants and animals. A final food group is made up, for the most part, of organisms that are small and simple. These are the organisms that feed upon dead and decaying plant and animal tissues. Various bacteria, fungi, and some flowering plants belong to this group. They are called the ***saprophytes*** (*sap*-roh-phyts).

We take saprophytes more or less for granted, because we rarely pause to consider what they do. Yet saprophytes are quietly at work obtaining energy from the bodies of dead plants and animals, and returning materials from their bodies to the soil, air, and water. Now, these materials can be used again to produce new generations of living things.

In any community, all of the food groups are likely to be represented. But some groups may be better represented than others. Each group is composed of a number of species or populations.



7–7. Two examples of saprophytes. Left, birds-nest-fungi; right, indian pipe. (*Hugh Spencer*)

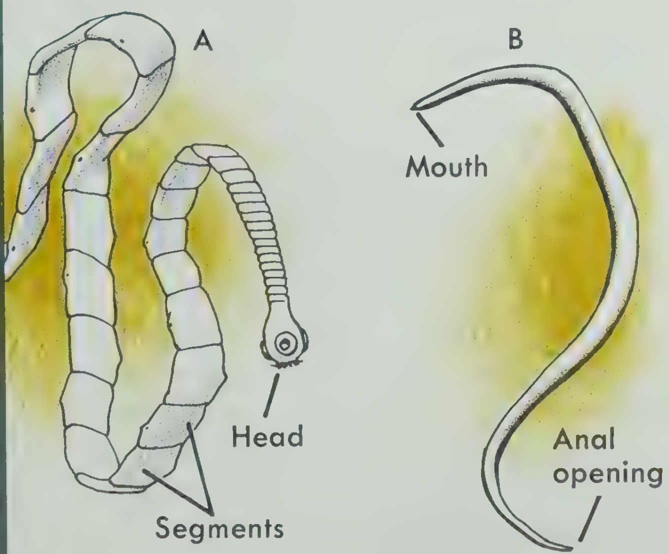
These populations increase and decrease as new individuals are produced and other individuals die.

TAPEWORMS AND ROUNDWORMS

Before leaving the subject of food groups, you should become acquainted with certain organisms. They are examples of parasites, and some of them are very important in human affairs.

If you remove the contents from the intestines of newly killed fish or frogs, and examine them with a hand lens, you are likely to find some wormlike organisms. Some of them may be tapeworms, like *A* in Fig. 7–8, and others may be roundworms, like *B* in Fig. 7–8. These animals belong to different phyla, but both types are parasitic.

You can study slides that bear small tapeworms or roundworms. The low power of a microscope or a projector will make their structures visible.



7–8. Two types of parasitic worms: (A) tapeworm; (B) roundworm.

TAPEWORM PARASITES Focus on a specimen of a tapeworm. Such a parasite usually lives part of its life in the intestine of its host. Its head, which bears four suckers and sometimes a ring of hooks, serves to attach the worm to the lining of the intestine. The rest of the tapeworm's body is made up of segments. New segments are formed next to the head, so the oldest and largest segment is at the end of the body.

Locate the *head, suckers,* and *segments* of your tapeworms specimen. Notice that there is no mouth opening. In fact, a tapeworm has no digestive canal.

ROUNDWORM PARASITES Now examine a roundworm specimen in the same way. Are there any segments? Here you find a mouth and an anal opening. Through the body wall, you can see a digestive canal that runs the length of the body.

Roundworms may also live in the intestines of their hosts. But some roundworms invade other tissues of a host's body. And some roundworms live as parasites in plants. Other roundworm species are not parasitic.

ANALYSIS After observing two general types of parasitic worms, prepare answers to the following questions in your notebook:

1. How do you suppose a tapeworm obtains food? How does this food enter the tapeworm's body? Give reasons for your answers.
2. What effect might a tapeworm, living in the intestine, have upon its host?
3. How do you think a roundworm, such as the one you examined, would obtain food?

4. Which do you think is more complex, a tapeworm or a roundworm? Why?

COMMUNITY FOOD CHAINS

You probably have noticed that, aside from the food makers, food groups are dependent upon other organisms. The herbivore must have plants to eat, the carnivore must have animals to devour, and the parasite must have suitable hosts. Even the saprophyte requires dead plants and animals to feed upon.

Food chains in ponds. What happens to the foods that the food makers provide? The answer is that they are passed along from one organism to another through a complex series of *food chains.* For example, the algae in a pond make foods. The algae die and bacteria of decay feed upon them. These bacteria serve as food for protozoa. Later on, the protozoa are eaten by tiny crustaceans. Now a minnow eats the crustaceans, and the minnow is captured and consumed by a crayfish. A large fish comes along and eats the crayfish, but the fish soon falls victim to a hungry turtle.

So the basic food made by the algae is passed through a series of other organisms to the ultimate benefit of the turtle. Each organism represents a link in a food chain. There is an infinite variety of food chains in nature, and another one might produce the same end result. For instance, pond algae may be eaten by a small fish. The small fish is gobbled up by a somewhat larger fish. Parasites kill the larger fish, and its remains provide food for a crayfish. Now a bullfrog eats the crayfish, and a turtle eats the bullfrog. So again, the chain proceeds from the algae to the turtle, but by a different route.

You should note one significant thing about such a food chain. Each organism in the chain uses up some of the energy in the foods the algae produced. So the amount of food-energy passed along grows smaller as the chain becomes longer. Only a small part of the original food energy reaches the turtle.

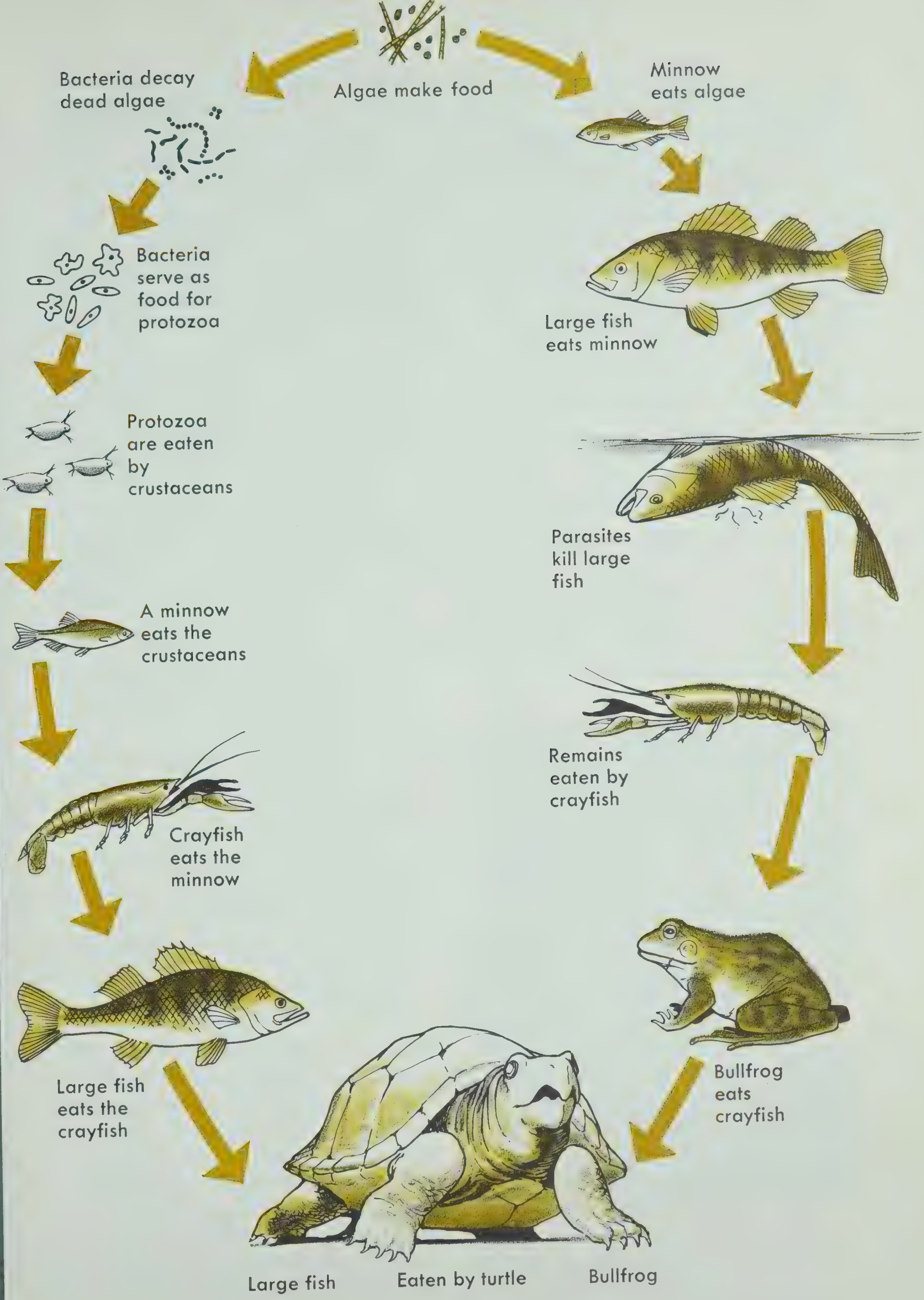
Another important point is that man may profit from a good many food chains that exist in nature. In the preceding example, for instance, a man might use either the fish, the bullfrog, or the turtle as food.

Other food chains. Such food chains exist in all communities, and they branch and rebranch in many directions. There are food chains in the sea, on the land, and in the soil.

In a land community, for instance, a tiny insect feeds on a green plant. This insect is eaten by a beetle, and the beetle ends up in the stomach of a bird. A fox comes along and makes a meal of the bird. Suppose the fox continues to live, because it escapes its enemies. In time, the fox dies of old age, and its remains provide food for the saprophytes.

The web of life. You can now begin to see that food relationships in any community are very complex. Populations of the community interact in a number of ways. Some of these interactions involve food, and others do not. So we sometimes say that a *web of life* exists. Because there are so many subtle interactions among organisms in a community, it is not always easy to find out just what is happening.

It is possible, however, to learn some things about interactions by studying organisms in a less complex



7–9. Both of these food chains have different connecting links, but the first and last links are the same.

situation. For example, a small artificial community, having a limited number of members, may be set up in the laboratory. It is then possible to observe at least some interactions. But we must realize, that in such an artificial community, the organisms may not behave just as they do in a state of nature.

LABORATORY COMMUNITIES

You can set up small, artificial communities in sealed containers. The sealed containers serve to remove the organisms as completely as possible from outside influences. Small jars with screw caps, as shown on page 108, will serve this purpose.

MINIATURE LABORATORY COMMUNITIES Three jars should be about two-thirds full of boiled water. Boiling the water will get rid of many *microorganisms* that may be present. These microorganisms are such things as bacteria, protozoa, and tiny fungi, that can only be seen with the aid of a microscope. The boiling will also serve to drive off gases that may be dissolved in the water. The air space above the water in each jar will act as a tiny atmosphere. Allow the boiled water to cool to room temperature. Then stock the jars as follows:

1. Place a small aquatic animal in the first jar. A water snail or a small crustacean will be satisfactory.
2. Place a small piece of green, aquatic plant, such as *Elodea* or some green algae in the second jar.
3. Place an aquatic animal and a piece of aquatic plant in the third jar.

Now seal the jars tightly with the screw tops. If there is any possibility of air leaking into the jars, put collodion, which will soon harden, in the space between the jars and the caps. Keep the jars at room temperature and in a lighted place for several days.

Based on what you already know, what do you predict will happen to the organisms in each of the three jars? What are your reasons?

Observe the organisms daily for several days. Record any observed changes in your notebook. Were you surprised with your results?

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did the organisms seem to fare better in any one of the jars? Not as well in any jar? Explain your results.
2. Did your observations seem to indicate that the plant and animal in jar 3 interacted? What evidence do you have for your answer?
3. If other students set up similar jars, were their results like your own? If not, how can you explain the differences?
4. Do you think there were only two kinds of organisms involved in your experiment, or do you think some unseen microorganisms might have been present? What evidence do you have?

OTHER TYPES OF LABORATORY COMMUNITIES Assuming that a pond community is made up of certain numbers of plants and animals, including microorganisms, what might happen if the numbers of any one of these types were suddenly changed? If, for example, the number of microorganisms were suddenly increased, would the other organisms be affected? If so, how? We can gain some

information about this question by setting up another series of laboratory communities.

Fill each of four jars about two-thirds full of water. But this time, do not boil the water. Place a small, aquatic animal and some green aquatic plants in each jar. Do nothing more to the first jar. Add one-half of a dried pea or bean seed to the second, two dried peas or beans to the third, and five to ten dried peas or beans to the fourth. The dried seeds will provide a food supply for microorganisms, and we can expect them to increase rapidly in numbers. Seal the jars as before, and keep them in a lighted place at room temperature for several days. Observe the jars daily, and record any changes in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

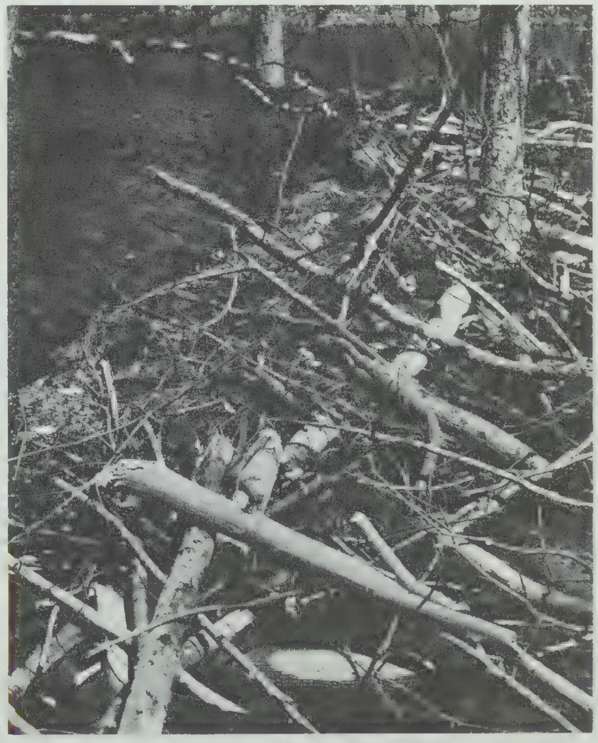
1. What effect did the increased numbers of microorganisms seem to have on the plants and animals in your laboratory communities? Explain.
2. What do you predict will happen to the microorganisms if the jars are left sealed for many days? Why?
3. Biologists often refer to the "balance" of populations in a natural community. Would you say that any of your laboratory communities were "balanced"? Give your reasons.

SUCCESSIONS IN NATURE

When you observed the organisms in a pond culture over a period of time, you no doubt found that changes had taken place. Some types had become more numerous, and other types all but disappeared. The changes may have been quite marked, because you had removed the culture materials from a natural community and set them up in an artificial community. As a result, there was considerable change in environment, and changes in population were sure to follow.

But environmental change is also the rule, rather than the exception, in natural communitites. Populations change with the change in seasons. They also change over a long period of time. The plants and animals, best adapted to the environment at a given time, are the ones that tend to survive. The nature of environmental change, then, determines which species will be best adapted.

Living things change the environment. Living things themselves can bring about changes in the environment. For instance, a small mountain



7–10. Beavers are able to change their environment by building dams. (*Rue from Annan Photo Features*)

valley will almost surely have a stream bordered by a growth of bushes, trees, and other land plants. A family of beavers wanders into the valley. These animals soon begin to dam the stream at some point. Before long the lowlands bordering the stream above the dam are flooded. Land plants growing in the area are now doomed. Most of the trees and bushes soon die. In time, their place is taken by plants that can live in the water. What was once a land community is now a pond community.

Changes of this kind go on all the time in any community, but most of them are slow changes, that you would not notice unless you were looking for them. Plant and animal materials decay and are added to the soil. As a result, the nature of the soil changes. To put it simply, the plant and animal populations are changing the environment. This is another example of the complex web of life.

The nature of successions. One of the interesting things we observe in nature is the manner in which a forest comes into being. One type of forest the early settlers found in North America was a growth made up largely of white pine and hemlock trees. These trees dominated the scene, and except for fallen needles, the forest floor was largely bare.

White pine and hemlock trees do not grow as fast as many trees about them, but they grow taller. They can also survive in moderately shaded locations. They must have a fairly moist soil. The settlers found pine and hemlock forests in many portions of the northeastern area of the United States,

7–11. The succession of a pond community ending in a land community.

where the environment favored their development.

What happens when you cut off a large area of such a forest? Does a new forest of white pine and hemlock start right in to grow again? Not at all. Rather, a long succession begins. During the first two or three years, the ground is largely covered with weeds. Here and there grasses begin to appear. Time passes, and young trees begin to rise above the grasses and weeds. These young trees are a mixture of ashes, birches, soft maples, poplars, and various other species. The white pines and hemlocks are on their way, but more slowly.

So the mixture of young trees grows, and after 10 to 15 years fast-growing trees and bushes are casting a heavy shade on the ground. The weeds and grasses are disappearing or have already died because they can no longer get the sunlight necessary for growth. And the trees are in competition with one another for this all-important sunlight.

Forty or 50 years pass, and the young forest is still a mixture of tree species. But here and there, the shade-tolerant white pines and hemlocks can be seen. Slowly but surely, these trees begin to win out in the competition. Their success is due to two factors. First, they are adapted to the existing conditions of life, and second, they are able to tower above their competitors, and these competitors cannot tolerate the shaded conditions in which they now live.

A hundred years, or perhaps 150 years later, the original type of forest is

7–12. A forest succession ending in a climax forest community.

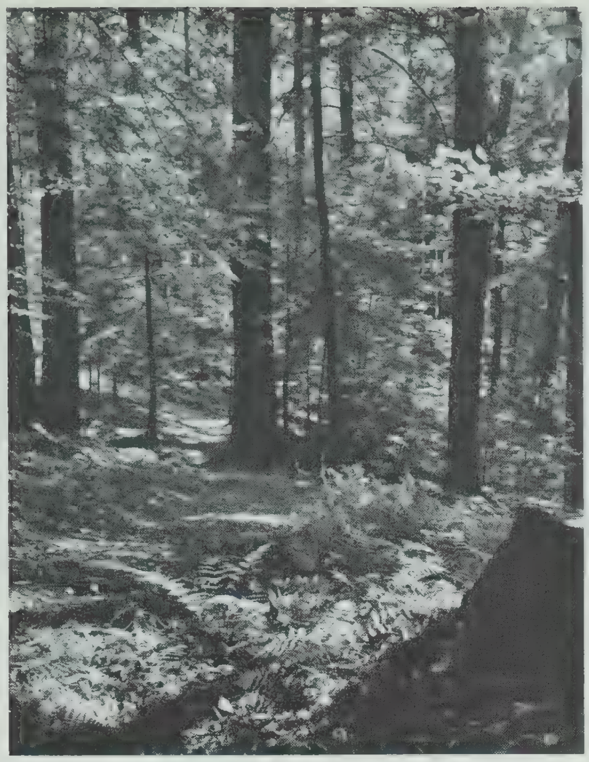
restored. This can only happen, however, if man does not interfere with the succession, and if the environment does not undergo considerable change. Then, once again the white pines and hemlocks dominate the forest, and its shaded aisles may be much as they were years before. It is now what we call a *climax forest.* The climax vegetation is one that will maintain itself indefinitely, unless environmental changes are marked.

But the trees are only part of this story of succession. While the new forest has been growing, the animal population has also been going through a series of changes. While there were only weeds and grasses growing on the land, a group of birds and small mammals, that feed upon plant seeds, was well represented. Later, as the weeds and grasses disappeared, these animals went elsewhere, and were succeeded by a group of animals that ate the buds of trees, acorns, and nuts. Finally, the forest provided shelter and food for still another animal group that used it largely as a place of refuge.

You should not conclude that the preceding description represents the only type of succession. Actually, there are many others in which the dominant plants of the climax growth are different kinds of trees, or even prairie grasses. There are even climax growths that feature cactus plants and sagebrush.

The balance of nature. From what has gone before, you can see that it takes time for a community to reach a climax development, and also, that populations change while a succession is in progress. In fact, populations that flourish in the early stages of a succession often vanish before the climax growth is achieved. Another important fact is

7–13. Three stages in a natural succession on an old field. (A) Vegetation composed mainly of grasses; (B) seedlings and a few saplings; (C) fully-stocked field with trees and grass. (*U.S. Forest Service*)



7–14. Climax forest growth, Cook Forest State Park, Pennsylvania. (*Grant Heilman*)

that a climax community is relatively stable. The various food groups of the community tend to be so-balanced that the herbivores, the carnivores, the omnivores, the parasites, and the saprophytes can all find food. Relative numbers of food makers and consumers remain about the same.

When this state of affairs is attained, you have a *balance in nature.* No consumer group is so large that it threatens the survival of other groups. The balance, of course, is always being readjusted, because changes in the environment make this necessary. But as long as these changes are minor, the climax community can continue to exist, and will usually do so.

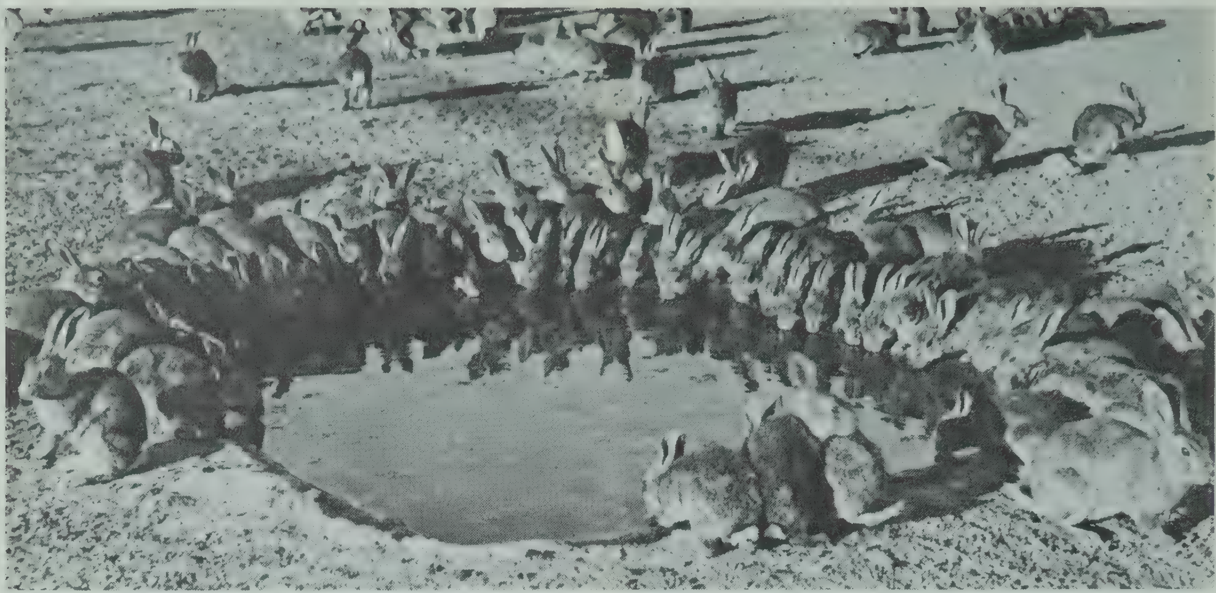
Man and the balance in nature. When man moves into a natural community, the balance among food groups is almost certain to be disrupted. For one thing, man brings with him various domesticated animals and cultivated plants. Along with them, come weed seeds and all sorts of microorganisms that cause plant and animal diseases. Man sometimes proceeds to do away with climax growths to make room for his gardens, fields, and pastures. And naturally, when the climax growths are removed, successions begin again.

In time, forested areas are converted into fields. The plants and animals favored by a forest environment are largely gone, and are replaced by plants and animals that prosper in meadows. So the various food groups have lost some of their members, and have acquired new ones.

If you observe the average country roadside, you see one sort of thing that may be expected. The roadside is being torn up every now and then by cutting, grading, and repairing. So it is always in some early stage of a succession. Generally, it is covered with weeds, which include some of our worst pests.

Some years ago, men introduced the European wild rabbit into Australia, hoping that this animal would provide an inexpensive supply of food and fur. In their new home, the rabbits found few dangerous enemies, and plenty of food. So the rabbits prospered. Before long the rabbit population became a serious problem, because they were eating large quantities of plants. To be sure, the rabbits did have some value as food and furbearers. But on the other hand, they destroyed the vegetation on large tracts of land, and this led to land loss by erosion, and to problems of flood control.

Through sad experience, men have learned that once the balance in nature is upset, it is very difficult to re-establish this balance in anything ap-



7–15. A part of the tremendous rabbit population that once existed in Australia. (*Australian News and Information Bureau*)

proaching its original form. And although a new type of balance may be developed in time, the nature of the new balance is not easy to predict or control. As a result, we have experienced many surprising and undesirable (from our point of view) consequences, growing out of activities that serve to change natural communities.

But it is possible for man to live in a community that is reasonably well balanced. In such a community he is not likely to be overwhelmed by numerous plant and animal pests. It takes time, however, for a community to absorb man and his works. And balance is not achieved, unless the land is used wisely.

WORD MEANINGS

On a sheet of paper in your notebook, copy the list of words in the first column. Write in the statement from the second column that goes best with each of these words.

1. balance in nature	A series of organisms through which food material is passed.
2. carnivore	Small organism that lives at the expense of some other plant or animal.
3. climax community	A plant eater.
4. food chain	A flesh eater.
5. herbivore	An organism that eats a variety of both plant and animal tissues.
6. host	An organism fed upon by a parasite.
7. omnivore	A nongreen plant that causes decay.
8. parasite	
9. saprophyte	
10. succession	

A series of progressive changes in community populations.

A group of populations that can maintain themselves over a long period of time.

A situation in which the relative numbers of food makers and consumers remains about the same.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The lives of organisms within a biological community are closely interrelated.
2. Pound for pound, plant food is more nourishing than animal tissue.
3. Cattle, horses, and sheep are herbivores.
4. Foxes and mink are omnivores.
5. Omnivores have an advantage in that they are not restricted to any one kind of food supply.
6. Parasites are generally smaller than their hosts.
7. Although parasites feed on the tissue of a host, they generally help the host more then they harm it.
8. Saprophytes are organisms that get energy by digesting dead material.
9. The oldest and largest segment of a tapeworm's body is the segment next to the head.
10. Parasitic roundworms have no digestive canal.
11. The way in which energy from the sun is used in green plants to make sugar is called a food chain.
12. Some energy is used by each link in a food chain.
13. Organisms are known to act in an artificial community exactly as they do in a natural community.
14. Bacteria, protozoans, and tiny fungi are termed microorganisms.
15. As water boils, gases dissolved in the water are driven away.
16. Environmental and population changes can be expected in any natural community.
17. The organisms best adapted to the environment are the ones most likely to survive.
18. Although the environment has a great effect on living things, living things seldom affect the environment.

19. White pine and hemlock trees are the dominant forms in certain forest communities, because they grow faster than do other types of trees in those communities.
20. When a white pine-hemlock forest is cut down, it can be restored in from 10 to 20 years under natural conditions.
21. The climax vegetation is usually the first vegetation to reappear after a forest has been destroyed.
22. As the plant populations in a community change, the animal populations can be expected to change also.
23. In a balanced community, no consumer group is so large that it threatens the survival of any other group.
24. When man enters a natural community, the balance is almost always disturbed.
25. Once the balance of a natural community has been upset, it is usually quite easy for man to restore the balance to its original form.

DISCUSSION QUESTIONS

1. In what ways are some consumers limited to certain foods? Give examples.
2. Distinguish between the processes of photosynthesis and chemosynthesis.
3. What is it about plant material that makes it less nourishing than animal tissue?
4. What is the advantage of having domestic animals that are plant eaters rather than animal eaters?
5. Describe what is happening when something decays.
6. Explain the processes by which chemicals of a living thing may be used again and again by other living things.
7. In what ways are tapeworms and parasitic roundworms alike? Different?
8. Describe a food chain that might occur in a forest community. In an ocean community. In a desert community.
9. In what ways are the food relationships in a natural community better described as a "web" than as a "chain"?
10. Explain what is meant by the statement, "The amount of food energy passed along grows smaller and smaller as the chain becomes longer."
11. Describe ways by which living things may alter their environments. Give examples.
12. Describe ways in which man has upset the balance in nature. Could any of these upsets have been prevented? How?

THINGS TO DO

1. Using drawings or pictures, illustrate food chains that occur in pond, forest, desert, grassland, and ocean communities.
2. Clear away all plant growth from a small plot of land. Observe the plot from time to time to see if a succession occurs.
3. Collect specimens of the dominant species of plants from various natural communities that occur locally. Preserve the specimens by following the directions on page 111.
4. Using drawings or pictures, illustrate factors that cause successions to begin. Illustrate the expected steps in each kind of succession. Be sure to include natural factors, as well as those involving activities of man.
5. Take a walk through a forest, meadow, or park. Observe the ways in which living things are altering their environments. Report your findings to the class.
6. Prepare a list of ways in which human activities have altered natural communities in your locality. Prepare similar lists of problems that these changes have created, and things that might be done to solve such problems.
7. See if you can set up a small balanced aquarium. Such an aquarium should contain both plants and animals and should "take care of itself." Refer to the directions on pages 254–256.

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CHAPTER 8

Physical Factors and Life

You have learned from your studies that physical factors are a very important part of any environment. Because these physical factors vary so greatly, environments may be very different from each other. Thus, in certain areas of warm countries where there is a lot of rainfall, you may find a dense jungle growth. But, in the same countries where rainfall is scanty, you may find a desert.

Many plants and animals are adapted to a certain type of environment. The environment where they are usually found is called their ***habitat*** (*haba*-tat). For instance, the habitat of a sunfish is a freshwater pond or lake. If the sunfish is dipped up in a net and placed on the land it is no longer in its natural habitat. It still has an environment, of course, but not an environment that favors its survival. If the sunfish fails to get back in the water, it will soon die. Are you able to think of any instances where a person might have difficulty in adjusting to a particular environment?

TEMPERATURE EFFECTS

One of the physical factors of any environment is temperature. Most organisms are favored by temperatures that range between 40°F and 105°F. You may think that 105°F is too warm for comfort, but some bacteria feed, grow, and divide actively when their surroundings are that warm. Some algae, in fact, live in hot springs where the temperature is about 200°F. Certain bacteria have survived boiling temperature (212°F), and some seeds have sprouted after being heated well above the boiling point. Of course, how long they are held at high temperature may be an important factor. Also, not all organisms can tolerate temperatures much above 100°F. Many animals begin to show signs of discomfort when temperatures rise into the nineties.

At the other extreme, a number of simple animals and their eggs are known to survive in freezing temperatures. This is also true for various plants and plant seeds, as well as cer-

8–1. Some algae are known to live in hot water springs. (*Gym from Annan Photo Features*)

tain microorganisms. The fact that water has been frozen into ice by no means guarantees that the ice is free from disease-causing organisms.

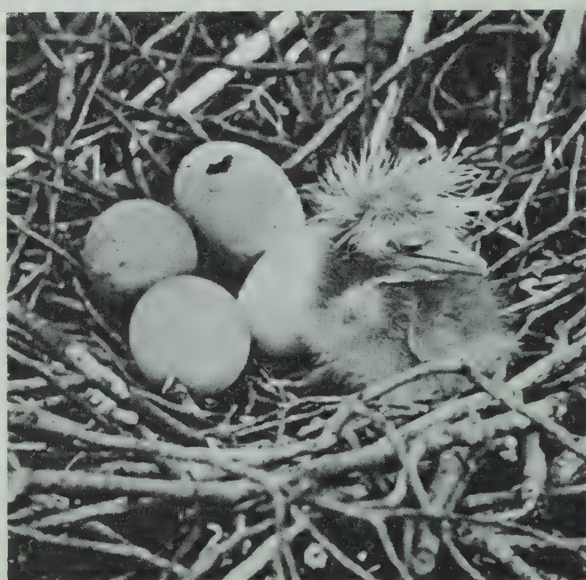
As you might suspect, the conditions under which an organism is either heated or cooled make a difference in the effect on the organism. How rapidly the temperature rises or falls is one factor. The amount of water content in the organism at the time is another.

Extreme heat and cold are barriers. So you see that some living things survive freezing cold and boiling heat, but many others do not. Growing season temperatures generally range between 40°F and 100°F, and populations reach their peak numbers between these temperatures.

Warm-blooded animals are able to remain active even though their surroundings are frozen. This select, warm-blooded group includes only the birds and the mammals. Their blood temperature varies within a normal daily cycle, which may be between 102°F to 115°F in the case of a bird, or an even greater range in a very young bird. In most mammals the range is not as great, and in man it is confined to a single degree.

Warm-blooded animals pass through their daily cycle without respect to what the temperatures around them may be. So the warm-blooded mink and various other mammals are abroad seeking food on cold winter nights. Birds are represented by the night-hunting owls. Some other warm-blooded species, however, are likely to remain in their retreats, except in periods of relatively mild weather.

Cold-blooded animals have body temperatures which change as the temperatures around them change. Included in this group are all of the simpler organisms, as well as insects, arthropods, fish, amphibians, and reptiles. These animals are more at the mercy of climate and weather than are the warm-blooded types. If tempera-



8–2. The temperatures of newly hatched birds vary greatly. (*Walter Dawn*)

8–3. Owls are warm-blooded, which is an aid to this night-hunter. (*Carl Zeiss*)

tures drop down toward the freezing point, they are unable to remain active. Many small, simple animals are killed by the winter cold, and others go into various retreats in order to survive. Fish, turtles, and other aquatic types, for instance, can continue to live in ice-covered ponds, provided the pond water contains enough oxygen. A housefly may hide away in a crack in a heated home, and emerge again the following spring. Various other animals, that are small enough to escape notice, live on in heated buildings.

Plants exist in much the same way as cold-blooded animals. Many land plants die as winter approaches. Others live through the colder months, but their life activities proceed at a reduced rate.

What about the plants and animals that die in fall and winter? Certainly, such species are back again when the warm weather returns. The answer, of course, is that before they die they leave spores, seeds, and eggs behind them. So the same kinds of organisms reappear the following year.

Human reaction to temperature changes. The degree of discomfort we experience on warm days depends in part upon how much water vapor is in the air. The higher the temperature, the more water vapor the air can hold. So when the thermometer registers 95°F and the air has a high moisture content, we have a very "muggy" day. Everyone suffers discomfort. But if there is little water vapor in the air, 95°F is a more bearable temperature.

Life activities that go on within the human body release energy in the form of heat. At 68°F the resting human body gives off excess body heat without any special effort. Some of this heat is discharged in the air that comes from the lungs, and some is discharged through the skin.

When the temperature around us rises or we engage in exercise, we begin

8–4. Fish are able to live through the winter in ice-covered ponds. (*Michigan Tourist Council*)

8–5. Which of these environments would you expect to be more humid? (*Left, Walter Dawn; right, Phoenix Chamber of Commerce*)

to perspire, and thus more body heat is given off through our skins. As perspiration evaporates, the body surface is cooled. But, if the air is full of moisture, perspiring does not bring much relief because the perspiration evaporates slowly. When the air is dry or there is a breeze, perspiration evaporates rapidly, and the cooling effect is increased.

TEMPERATURE AND THE GROWTH OF BACTERIA

When you kept dried beans or boiled wheat grains in open culture bowls of water, you found that many bacteria began to appear in the cultures. You might ask whether you can tell how fast the bacteria population is growing. Biologists have developed ways of counting bacteria in such a culture, but the methods are rather complex and require special equipment. It is possible, however, to get some idea about the numbers of bacteria present in certain cultures by using the stain called *methylene blue.*

A METHYLENE BLUE TEST You have used methylene blue before (see page 129). It has a *blue color* in the presence of oxygen, and becomes *colorless* when oxygen is absent. Like other living things, many bacteria use oxygen. So if we add some methylene blue to a bacteria culture, in which the bacteria are numerous and have used up a lot of oxygen, the stain should soon lose its color. But if there are not many bacteria in the culture, the loss of color should be slower.

We can use the methylene blue method to test the growth of bacteria

populations in samples of milk. Perhaps you do not realize that milk normally contains bacteria. It is the bacteria in milk that cause it to spoil in time.

Divide a quantity of milk between three containers. Label the containers *A*, *B*, and *C*. Keep each container at a different temperature. You might have one in a refrigerator, one at room temperature, and one on or near a radiator. After 24 hours, take a 10 ml sample from each container, and put it in a clean test tube. Add 1 ml of methylene blue solution to each test tube. Put cork stoppers in the test tubes and shake to mix the stain with the milk. The milk should now be a *light blue* color. Set the test tubes aside at room temperature and observe them every half hour. Record how long it takes for the blue color to leave the milk in each tube.

Repeat this same test for several days on each of the three milk samples. Record your findings. Prepare a data sheet in your notebook like the following sample:

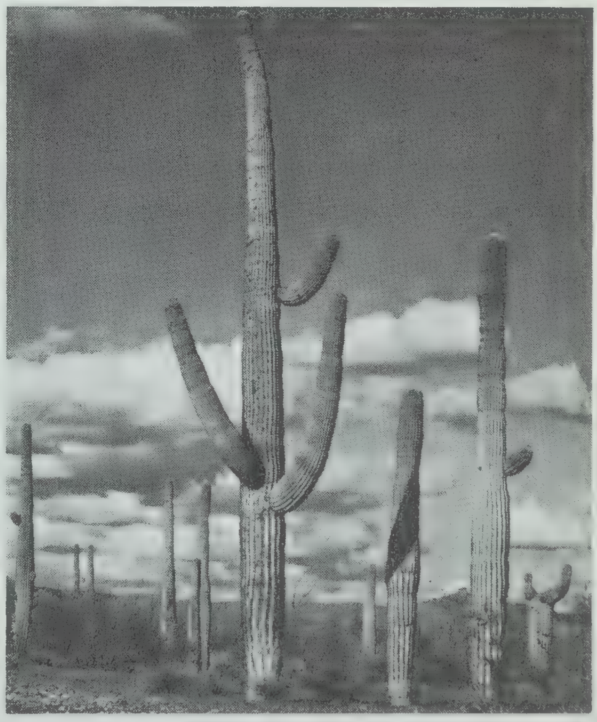
Sample (*A*, *B*, or *C*)	Age of Sample	Time for stain to become Colorless

ANALYSIS Prepare answers for the following questions in your notebook:

1. In which sample did the milk appear to contain the smallest population of bacteria? The largest population? How do you explain these results?
2. Would you say that a refrigerator is effective in slowing down the growth of microorganisms? What evidence do you have for your answer?
3. Do you think that boiling the milk would kill the microorganisms in it? Using the methylene blue test, how could you check your answer?

WATER AND LIFE

Since water makes up a large part of the living substance, its importance in the lives of plants and animals is obvious. As living things go, our own bodies are quite solid. Just the same, they are about two-thirds water. The milk you drink is about 86 percent water, which is not so surprising since milk is a fluid. But green beans are 89 percent water, spinach is 92 percent water, and lettuce 94 percent water. You might think this is about as watery as any living thing could be, but such is not the case, because some jellyfish that live in the sea are 98 percent water.



8–6. How is the giant saguaro cactus of Arizona suited to its desert environment? (*Phoenix Chamber of Commerce*)

Water is essential to active life. Plants and animals that live in desert communities may seem to "go without water." But actually, they are specially adapted to live where water supplies are scarce. A camel may not have a chance to drink for several days, but when it does drink, cells of its stomach lining absorb a large reserve supply of water. A cactus plant has no broad leaves to give off water to the air. The cactus plant is able to store large amounts of water that come from occasional rains, and thus it contains its own water supply during periods of drought.

The desert tortoise and many other desert animals rely upon water obtained from their food—moist stems, leaves, or small animals. Some other desert animals get much of their water from the fats and carbohydrates in dry seeds. You learned that water and carbon dioxide result from the chemical breakdown of such foods. Water from this source is sufficient to maintain the lives of certain small organisms, including the kangaroo rat, for long periods of time.

To be sure, some simple forms of life do lose water from their cells when water supplies are not available. In the case of these simple cells, death does not always result. But as their protoplasm loses its normal water content, life processes do slow down. Later on, they may be resumed at an active rate when ample water is available.

The water cycle. You have read about water vapor in the air, and you probably know that vapor condenses to droplets when clouds form. Water vapor from these clouds falls back to the earth as drops of water, sleet, or flakes of snow. Water that is returned to the earth's surface may run off in creeks and then rivers, and finally be added to the contents of the seas. But some of it soaks down into the soil, and even into the rocks that lie beneath the soil, and becomes *ground water.*

At the same time, water is evaporating from the surfaces of oceans, lakes, rivers, ponds, and the soil itself. Plants and animals are discharging water vapor into the air. The water vapor from these sources forms more clouds, and

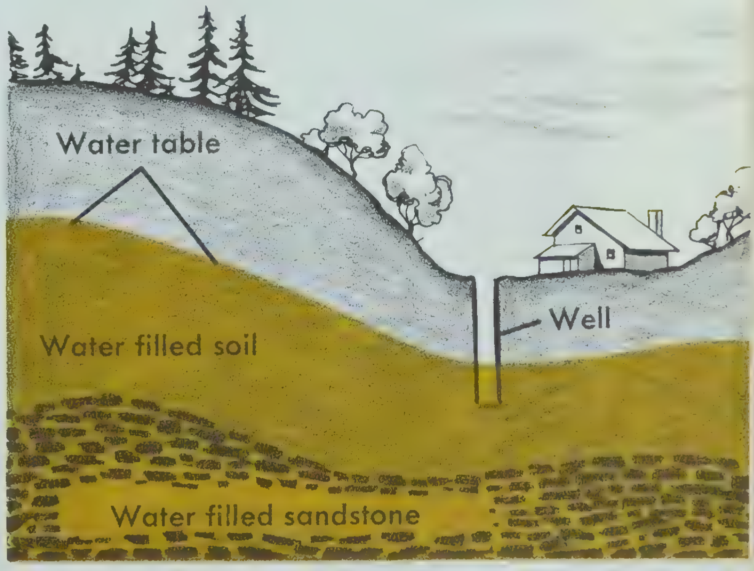
8–7. The kangaroo rat is able to survive on water produced in the course of releasing energy from food. (*U.S. Fish and Wildlife Service*)

8–8. Trace the pattern of the water cycle pictured above.

rains and snows come again. So here is a never-ending cycle. A given molecule of water may at one time be in a cloud, and later on in a frozen drift of snow, or in a rock beneath the earth's surface, or in the body of a plant or animal, or in the sea.

The water table. The water that is stored in soil and rocks is the water that fills our wells. In some places it also seeps out of the rocks and soils to form springs. It occupies a position in soils and rocks like that shown in Fig. 8–9.

The upper level of ground water is called the *water table.* A water table is shown in Fig. 8–9. In some low-lying



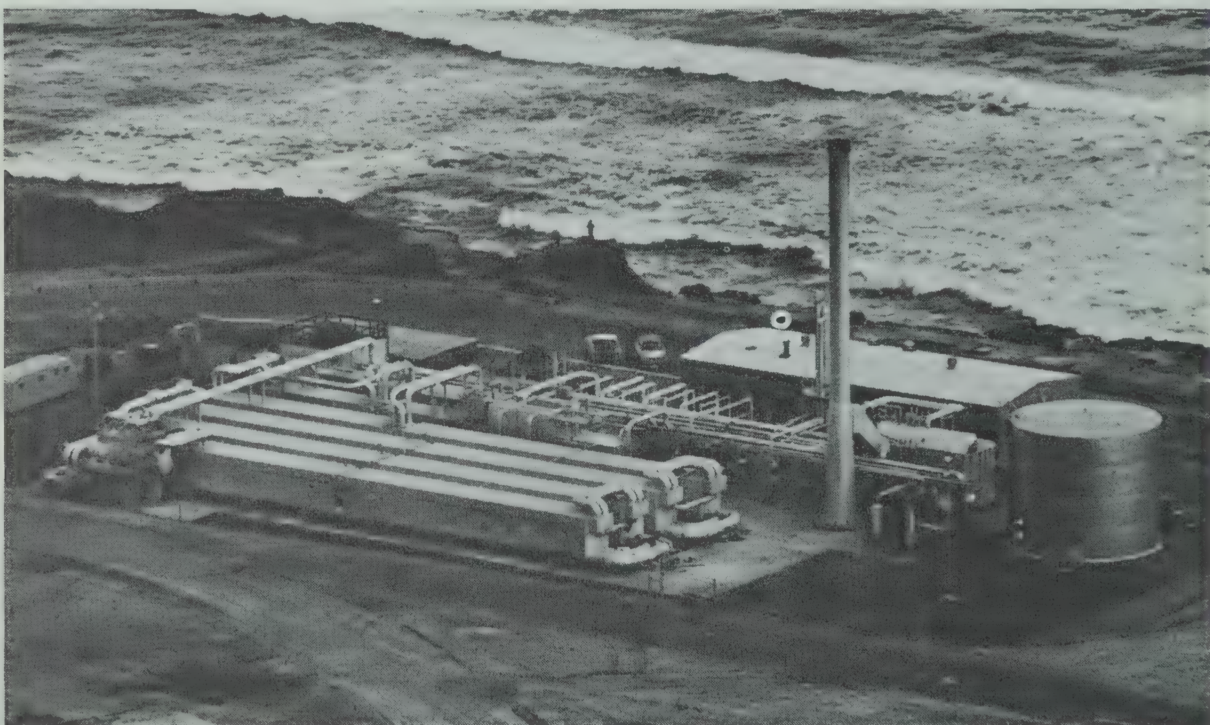
8–9. Diagram of a water table.

areas where there is a lot of rainfall, the water table is very close to the surface. In other localities it lies at a considerable depth. If the water table is near the surface, the soil above it tends to remain moist, and plants growing in this soil receive the water that they need. Wells that reach down below the water table remain filled, and springs continue to run.

But if, for any reason, the water table falls to a low level, a whole series of changes is set in motion. Wells go dry. Springs do not run, and the creeks they normally feed may contain no water during certain parts of the year. Rivers fed by the creeks may also dry up. Ponds become empty mud flats. Crop plants may fail to produce a harvest. From this you can see that soil water is most important, not only to wildlife, but also to our own welfare.

Water supplies. The seas cover more than two-thirds of the earth's surface, and they contain vast supplies of water. But sea water is full of salts, and is only used directly by the plants and animals that are adapted to life in ocean communities. We can obtain fresh water from the seas by removing the salts, but up to now, this has not been done on a large scale because of the expense involved. But in time, ways may be devised to get large supplies of fresh water from the seas.

Meanwhile, there are many desert areas that have fertile soils. To some of them we are able to bring water supplies that irrigate the land. Now crops can grow, and harvests are assured. However, much desert and near-desert land is not irrigated today, despite food shortages that exist in various parts of the world. Why is this so? The answer is quite simple. Not enough fresh water is at hand to do the job that needs to be done. As the human population increases, one of the real problems of the



8–10. This demonstration plant is able to produce one million gallons of fresh water from sea water daily. (*The Office of Saline Water Demonstration Plant, San Diego, California*)

8–11. This reclaimed desert in central Arizona is now highly productive. (*Phoenix Chamber of Commerce*)

future will be how to provide larger supplies of fresh water.

The lack of water supplies is another barrier to life. Without fresh water you cannot make the desert bloom, and dry land remains covered by sagebrush and mesquite. Where water is scarce, populations are small, and limited to organisms that have rather special adaptations.

PRESSURE EFFECTS

Most living things are found at or near the earth's surface. But many of them live in the oceans, and some of them spend at least part of their lives in the air.

Pressure of the air at sea level is about 14.7 pounds per square inch. If you live at sea level, you are used to this pressure and think nothing of it. But just the same, you depend upon air pressure to force a normal supply of air into your lungs.

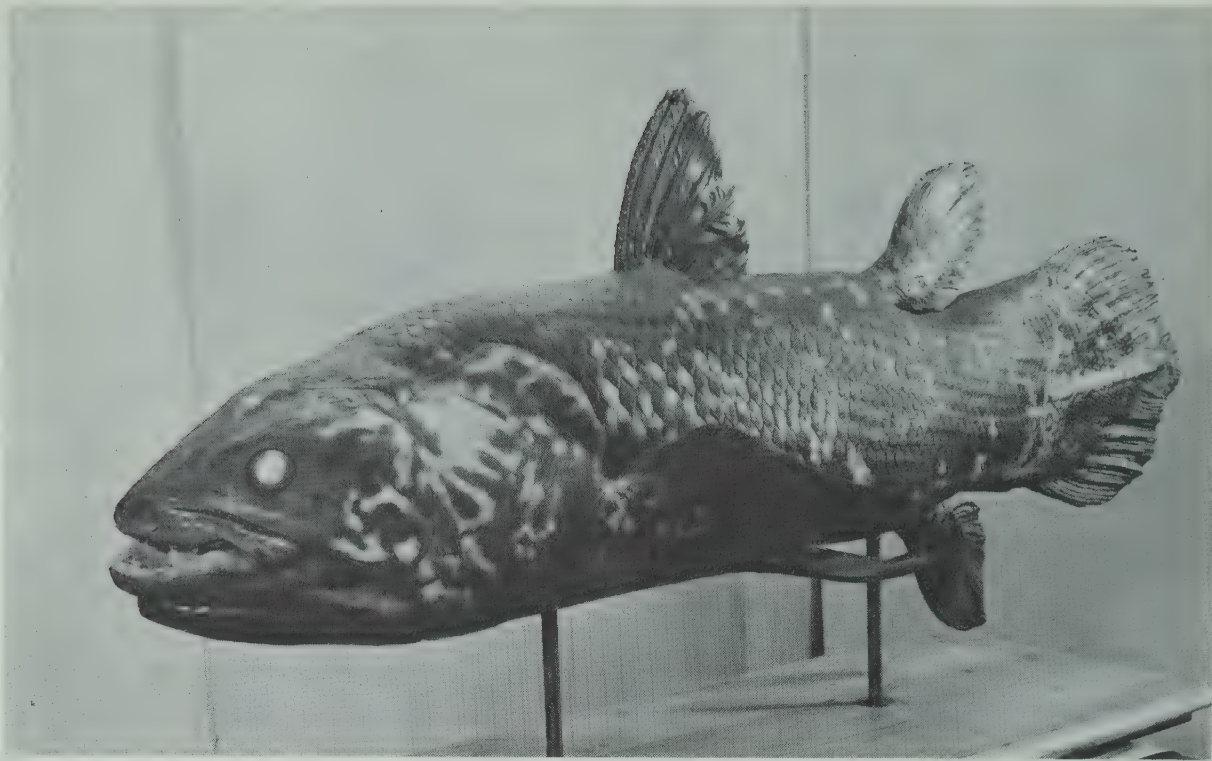
Now when you go either up or down from sea level, the *pressure* about you changes. As an airplane climbs, the pressure becomes less and less. As you go down into sea water, the combined pressure of air and water becomes greater and greater. It is very difficult to adapt to changes in pressure.

The deep sea community. As you go beneath the surface of the sea, pressure increases about 15 pounds per square inch for every 31 feet of depth. So if you are 93 feet beneath the surface, the pressure is 3×15, or 45, plus about 15 at the surface, which is a total of 60 pounds per square inch. At 620 feet beneath the surface, the pressure is about 315 pounds per square inch. You might try to figure what it would be at 6,000 feet, where we sometimes say the deep sea begins.

We now can understand that pressure upon the body of a deep sea animal is very great. But the animal is adapted in such a way that pressure within its body is *equally high.* This internal pressure offsets the pressure from without, and the animal is not crushed. But, an animal with such high internal pressure cannot survive at the surface.

Various animals exist below the 6000 foot level. In fact, one type of fish has been found at a depth of about seven miles. Others have been brought up in dredges from depths of about two miles, and with them come a number of invertebrate types. All of these animals are adapted to withstand great pressure.

The deep sea community is an odd sort of place. First of all, there is no sunlight, so green plants cannot grow



8–12. The *Latimeria,* discovered in 1938 off the Coast of South Africa, was a kind of fish thought to be extinct seventy million years. It was originally thought to live at great depths, but later evidence revealed that *Latimeria* lives in the shallower coastal waters of Madagascar. (*American Museum of Natural History*)

there. The living green plants of the ocean are all near the surface, since very little sunlight penetrates the water at depths below 600 feet. There is another type of light in the deep sea, however, because some of the animals that live there have luminous or light-producing organs on the outsides of their bodies.

How do the animals in the depths obtain food supplies? Of course, the larger animals may eat the smaller ones, but there has to be some basic food supply to start food chains on their way. The answer is that dead plants and animals are continually drifting down from the surface. This shower of dead organisms makes up the basic food supply of the deep sea community.

Human reaction to high pressure. Men in a submarine or a deep sea exploring vessel, like the U.S. Navy's *Trieste,* are protected against the great underwater pressures by the strong metal hulls of their ships. But men, who

8–13. The angler fish is a deep sea creature that has luminous organs. (*Perkins from Annan Photo Features*)

8–14. The *Trieste II* safely allows deep sea explorations. (*Official U.S. Navy Photograph*)

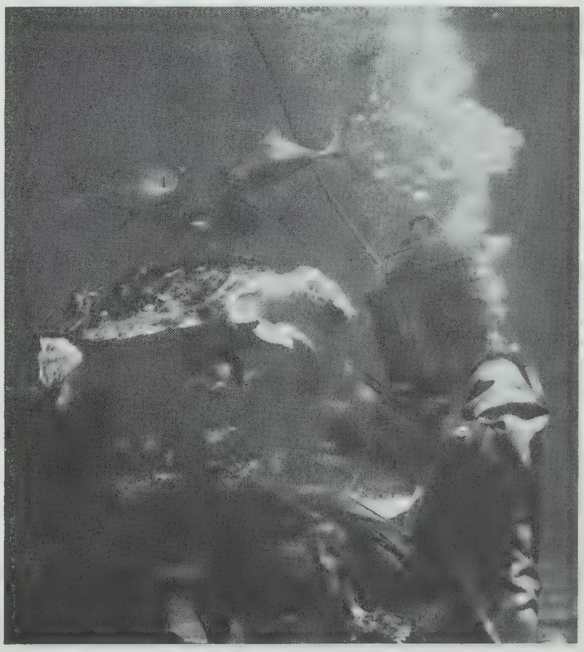
wear diving suits to descend hundreds of feet into the water, have a different problem. They get the air they breathe through an air hose. This air must be under enough pressure so that the diving gear does not press in upon the wearer and interfere with his breathing. So men in this type of gear must breathe air that is under pressure.

In boring tunnels under rivers, it often is necessary to hold back the water from seeping in upon the workmen. This is done by building a caisson, which is a sealed chamber at the working end of the tunnel. In the caisson the air is under higher than normal pressure. The increased air pressure holds back the water so that the men can work. But again, these men must breathe air that has higher pressure than the air in which they normally live.

Nitrogen makes up a large part of the gas mixture we call air. When you breathe air under normal or near-normal pressures, nitrogen enters your blood. It also passes out of your blood, and you are not affected by it. But if you breathe air that is under pressure for an extended period of time, a great amount of nitrogen collects in the blood and tissues. Then if the pressure is released suddenly, the nitrogen tends to rush out of the blood. Bubbles of nitrogen form in the blood, blocking blood vessels, and pressing upon nerves. This brings on an attack of *caisson disease*, which is sometimes called "the bends."

Caisson disease may result in death. Men who have been under high air pressure are put in a chamber where the pressure is also high. Then the pressure is released slowly from this chamber. As the pressure goes down, nitrogen leaves the men's blood, but not so rapidly as to produce an attack of "the bends."

Reactions to lowered pressure. Like high pressure, low pressure also may be a barrier which tends to keep living



8–15. Diving gear is essential to ocean exploration. (*Stan Wayman from Rapho-Guillumette*)

things out of areas above the earth's surface. When the pressure drops below 14.7 pounds per square inch, less oxygen enters the blood that is passing through the lungs. So cells of the body get less than a normal supply of oxygen, and the effect is soon felt.

For instance, if you have been living at sea level, and travel overnight to a city that is a mile high, your body cells will be getting less than a normal supply of oxygen. As long as you just sit or walk around quietly, you feel no ill effects. But if you engage in violent exercise, which demands a good oxygen supply, you soon find yourself "out of breath." The trouble is, of course, that your body is not adjusted to the changed conditions. But if you stay in the mile-high locality, the body will eventually adjust.

Several things happen before this adjustment to lowered pressure is complete. One is that the number of red cells in the blood increases. These red cells are the oxygen carriers of the blood. At high altitude each one of them gets a reduced oxygen load when it passes through the lungs. But this does not matter, because now there are more cells at work. Another change is that you begin to breathe more deeply. In time, breathing muscles in the chest become stronger. Also, the percentage of certain salts in your blood changes.

8–16. These Andean Indians of Peru have adjusted to the lowered pressure of their mountain environment. (*Hilty from Monkmeyer*)

The extent to which the human body can adjust to lowered pressure, however, is limited. This is the reason why the cabins of passenger airplanes are pressurized. At an altitude of 20,000 feet, air pressure is less than half of what it is at sea level. At sea level, blood passing through the lungs receives about 95 percent of the oxygen it can carry, but at 20,000 feet the amount of oxygen in the blood drops to below 70 percent of capacity. This happens because the pressure of oxygen in the lungs has dropped as the altitude and air pressure have changed, and a smaller quantity of oxygen is being forced into the blood stream.

Of course, no one in a pressurized cabin needs to worry about this. Sea level pressure is maintained by mechanical means. But in an open cockpit airplane, the case is very different, unless special gear is provided. Signs of altitude sickness are likely to appear at or about 15,000 feet, indicating that cells of the body lack an adequate oxygen supply. The senses of sight and hearing may become dulled, and muscular movements are not well controlled. Somewhere between 18,000 feet and 25,000 feet, consciousness may be lost, and if so, a person may die within a period of minutes.

Pressure as a barrier to life. You can readily see that either very high or very

low pressure will act as a barrier to life. Air content and pressure are physical factors which limit the distribution of plants and animals. To be sure, some animals live in the deepest parts of the sea. Some people live day after day in mountain homes, two miles or more above sea level. But when you consider the size of the earth, neither the deep-sea animals nor the mountain dwellers are very far from the earth's surface.

AIR AND PLANT GROWTH

Two of the gases in air that are intimately related to the welfare of green plants are oxygen and carbon dioxide. To test some of their effects upon plant growth, you may wish to carry out the following experiment.

A PLANT GROWTH EXPERIMENT Use four tall widemouth jars with screw caps. Put a few inches of moist soil in each jar. Plant several bean seeds in each jar, and wait until the young plants are about two inches in height.

Now leave one jar uncovered. Probably you will have to add water to this jar from time to time to keep the soil moist. Seal the cap on the second jar, using melted paraffin or collodion to make the seal airtight. Seal the third jar as you did the second, but first use a piece of tape to fasten a wad of wet steel wool to the underside of the cap. Moist steel wool will react with the oxygen of the air, and soon there will be less oxygen in this jar than in the others. Place a small, open vial of soda lime in the fourth jar. Then seal the jar. The soda lime will absorb carbon dioxide, and the air in this jar will contain less carbon dioxide than in the other three cases.

Put all four jars in a well-lighted place, and observe the plants daily for a week. Record the observations in your notebook.

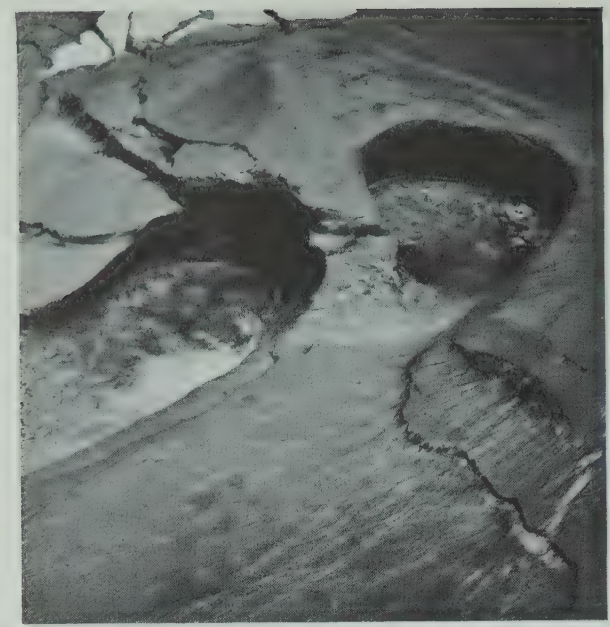
ANALYSIS Prepare answers in your notebook to the following questions:

1. In which jar did the plants grow best? In which jars was growth interrupted?
2. What effect does lack of oxygen seem to have on plant growth?
3. What effect does lack of carbon dioxide seem to have upon plant growth?
4. How would you answer the question, "Do green plants need air for growth"?

ROCKS AND SOILS

Rocks, and the soils that came from them, are physical factors that affect living things in many different ways. Rocks form the crust of the earth. These rocks are of various types, and contain a variety of chemical compounds. While you may think of rocks as being quite hard and durable, they are by no means everlasting. Rock surfaces are being worn away constantly by natural forces. Some of the softer rock surfaces may be worn away fairly rapidly. This is the first step in soil formation.

How soils are formed. A number of forces act upon rocks to break them up. Water in rock layers freezes and expands, and pieces of the rock may be broken off. Water also dissolves away



8–17. Running water is a powerful agent in rock weathering. (*Grant Heilman*)

some of the compounds that hold certain rocks together. Running water rolls rocks along the bottom of streams, and in time the rocks are worn down into small remnants. Sand, blown by the wind, scours away fragments from rock surfaces.

There are many such forces which act to break up the rocks of the earth's crust. As a result, many rock fragments are produced, some of them as large as pebbles, and other fragments that are very tiny.

Meanwhile, plants and animals live, die, and decay. Their remains are added to the rock fragments at or near the surface. A layer of *topsoil* is developed as a mixture of rock fragments and decay products. Beneath it lies the *subsoil,* which may be largely rock fragments. The topsoil with its decay products usually is the most fertile layer. It is interesting to note that many years may be required to develop a layer of topsoil a foot in thickness.

Types of soils. Several types of soils are likely to appear in any area. First, there are *gravels,* which are mainly composed of fairly large rock fragments of the pebble type. Gravels are not likely to contain a large amount of decay products, and water evaporates from them rapidly, because they are so porous.

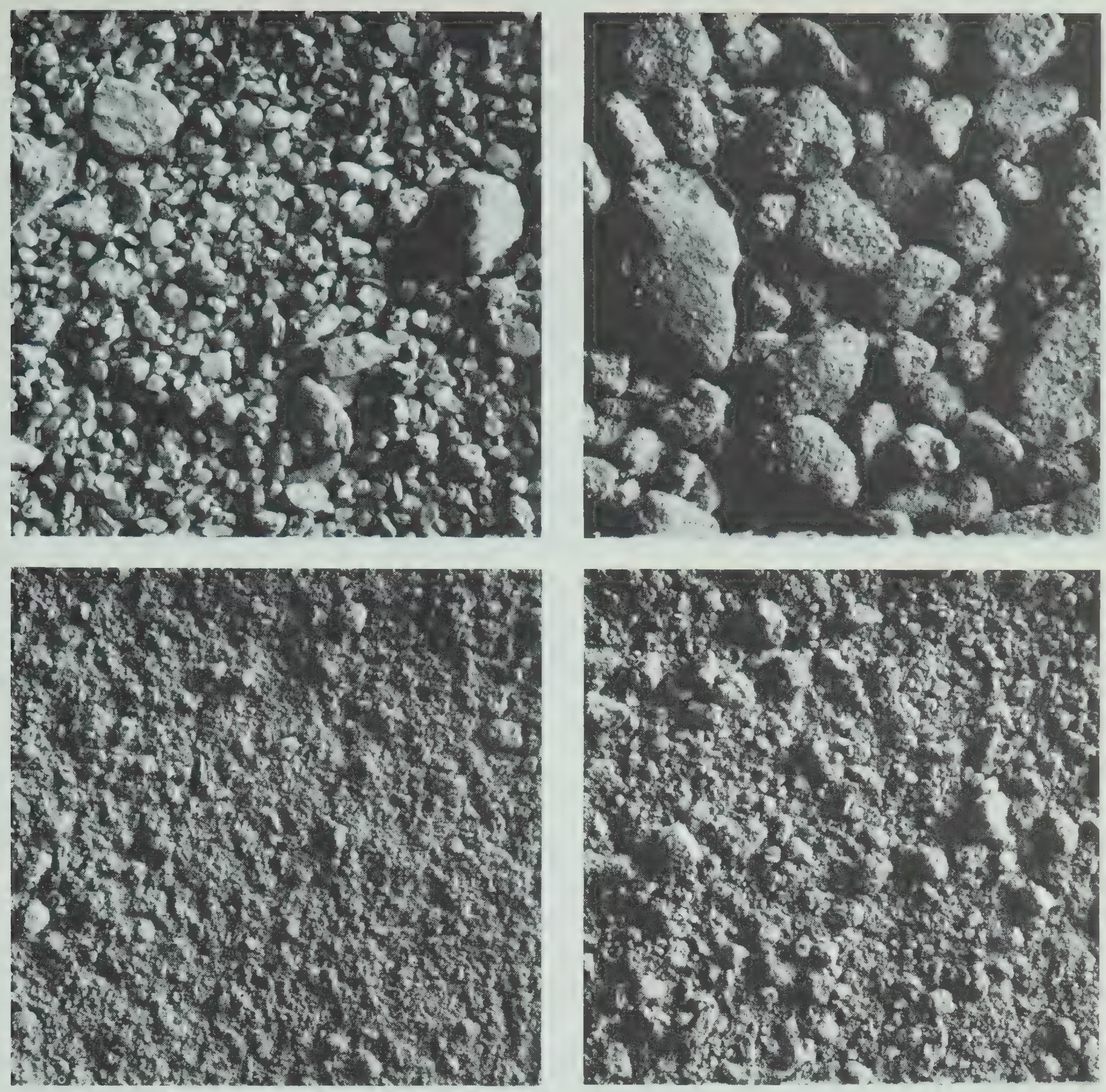
Soils known as *sands* are like gravels in that they are largely composed of rock fragments. But the rock fragments of sands are smaller than the rock fragments of gravels. Even so, sands tend to dry out rapidly after rains, but not as rapidly as gravels. Sands also have more tendency to retain decay products than gravels do.

Clay soils make up another group. They are the remains of a different type of rock from that which forms sand and gravel. They are exceedingly fine grained, hold water very well, and tend to keep the air out. So, like gravels and sands, pure clays are not likely to be good for crop production.

The soils we call *silts* are also fine grained, but not as fine grained as the clays. Silts are made up of particles that have been carried by water, and then deposited. For instance, a silt layer may be deposited on each side of a stream when the stream overflows its banks. Silt deposits often are quite good for crop production.

However, the soil we generally depend upon for producing our cultivated plants is *loam.* This soil is a mixture of all the other soil types. Of course it varies somewhat. One loam may be more sandy than another. Or it may contain a larger amount of clay. But generally speaking, loam soils hold moisture and decay products fairly well, and are porous enough so that air can penetrate them.

Soil erosion. Wherever there are land areas, the process called ***erosion***

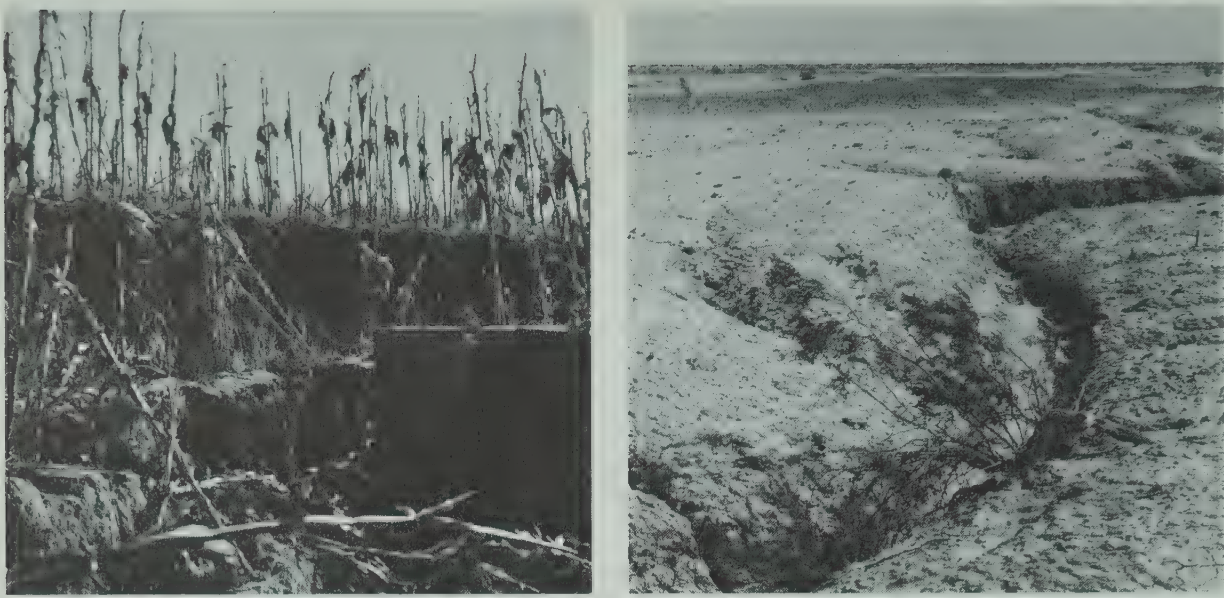


8–18. Four types of familiar soil. Top left, gravel; top right, sand; bottom left, clay; bottom right, silt. (*Grant Heilman*)

(ee-*roh*-zhun) goes on. This is a process in which the soils and rocks of the earth's surface are worn away. So even while soil is being formed, some of it is lost because of erosion.

The wind and running water that serve to break up rocks also act to remove soil from the surface. Rain falls upon the land, and some of it soaks into the ground and becomes ground water. But especially on hillsides, some of the water runs off in little rills that in time become gullies. This runoff water goes into creeks, rivers, and finally into the oceans. With it go the millions of soil particles that make the water muddy.

In dry areas, winds have a similar effect. They pick up soil particles and carry them for miles, producing what we call *dust storms*. As a result, the fertile topsoil may be removed from broad areas. Not so many years ago men tried to raise crops on some of the western drylands. For a short time the results were promising in some areas, because more than an average amount



8–19. Two types of soil erosion. Left, "slips," great chunks of farm land that break off, with unharvested corn still standing; right, erosion caused by constant winds and infrequent rains. (*Bureau of Land Management*)

of rain fell. But dry seasons came, and the topsoil dried out. Then enormous dust storms developed. A number of areas became dust bowls, and farmers had to leave them, because farming was no longer possible. Study Fig. 8–20. You may be interested in doing research to find out more about dust bowls.

Erosion has been going on for untold centuries, and will continue to go on in the foreseeable future. But the unwise use of land speeds up erosion enormously. This is a serious matter because fertile soil is lost, and it takes a long time for a fertile topsoil to form again.

8–20. A classic photograph of dust bowl country in the early 1930's. (*Library of Congress*)

WORD MEANINGS

On a sheet of paper in your notebook copy the list of words in the first column. Write in the statement from the second column that goes best with each of these words.

1. "bends"	Process by which land is worn away.
2. caisson	Sealed chamber containing air under high pressure.
3. cold-blooded	Particular environment to which an organism is adapted.
4. erosion	Water held in rocks and soil.
5. ground water	Mixture of rock fragments and decay products.
6. habitat	Disease due to nitrogen bubbles in the blood and tissues.
7. topsoil	Upper level of ground water.
8. water table	Organism with body temperature that changes with temperature changes of the environment.

Select the best answer to complete each of the following statements. Write the completed statement in your notebook.

1. Soil that is made up of particles, that have been carried in water and then deposited, is called (a) subsoil; (b) clay; (c) silt; (d) loam.
2. Soil that is composed of exceedingly fine-grained particles of a particular type of rock is called (a) gravel; (b) clay; (c) silt; (d) loam.
3. Soil composed of large rock fragments is called (a) clay; (b) silt; (c) gravel; (d) loam.
4. Soil made up of a mixture of soil types is called (a) loam; (b) clay; (c) sand; (d) subsoil.
5. Soil composed of very small rock fragments is called (a) gravel; (b) silt; (c) loam; (d) sand.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The temperature range between 40°F and 100°F is favorable for most organisms.
2. No known organisms can survive at the boiling temperature of water.

3. Without exception, disease-causing microorganisms found in water are killed by freezing.
4. The body temperature of some birds may vary as much as 10°F within a 24-hour period.
5. Fish, amphibians, and reptiles have body temperatures that change as the temperature of their environment changes.
6. Spores, seeds, and eggs are less affected by temperature changes than are adult organisms.
7. Perspiration evaporates less rapidly on a warm day when there is little water vapor in the air, than on a warm day when there is much water vapor in the air.
8. Large, rapidly growing bacteria populations cause methylene blue to lose its color more quickly than do small, slow-growing populations.
9. The human body contains nearly 90 percent of water.
10. Desert animals can occupy only those areas where drinking water is readily available.
11. In order for ground water to enter a well, the well must be deeper than the water table.
12. A great drop in the water table is unlikely to affect plant growth.
13. The main reason that desert lands are not used very often to grow crops is because the soil quality is poor.
14. Air pressure forces air into your lungs.
15. As altitude increases, air pressure decreases.
16. For every 31 feet of sea water, the pressure increases about 50 pounds per square inch.
17. Green plants growing on the bottom of the deepest parts of the ocean are the basic food producers for the deep-sea community.
18. "The bends" is a disease caused by bubbles of nitrogen forming in the blood vessels and blocking nerves.
19. Altitude sickness is caused by remaining too long in a pressurized cabin.
20. Wet steel wool can be used to remove carbon dioxide from the air in a sealed jar.
21. The breakdown of rock is the first step in soil formation.
22. Water is held to a greater extent by clay than by sand.
23. Erosion increases when man uses the land unwisely.

DISCUSSION QUESTIONS

1. In what ways do the physical factors of a desert differ from those of a jungle? How are they similar?
2. Explain the advantages that warm-blooded animals have over cold-blooded forms.

3. How are plants similar to cold-blooded animals?
4. Explain how various forms of life manage to survive the cold of winter.
5. Why is it that you feel more comfortable in dry air at 95°F than in moist air at the same temperature?
6. How is methylene blue useful in the study of bacterial population growth?
7. How is it that certain forms of life can exist in desert areas where water is very scarce?
8. What is meant by the "water cycle"?
9. What factors contribute to the rise and fall of the water table?
10. What problems face people who are interested in changing desert areas into farmlands?
11. Explain the problems encountered by organisms moving rapidly from areas of high pressure to areas of low pressure.
12. How is air pressure used to enable men to work at depths of 300 feet in the sea?
13. What causes the "bends"? How can this condition be prevented?
14. What is responsible for the discomfort felt by people who move from areas near sea level to high altitudes? How can this discomfort be reduced?
15. Explain the steps in soil formation.
16. What factors favor land erosion?

THINGS TO DO

1. Plan an experiment designed to test the resistance of some kind of seed to the temperature of boiling water. Have your teacher check your plans before you carry them out.
2. Using a clinical thermometer, check your mouth temperature several times during a 24-hour period. Find out how much your body temperature varies in this time.
3. Demonstrate the cooling effect on your skin by spreading some water on the back of your hand and allowing it to evaporate. Do the same thing using rubbing alcohol instead of water. See if moving air from a fan increases the cooling effect.
4. Using reference books, find out what you can about ways in which various animals are adapted to the desert and the deep sea environments.
5. Using pictures or sketches, prepare a bulletin board display to illustrate one or more of the following: (a) water cycle, (b) food chain in a deep sea community, (c) steps in soil formation, (d) land erosion.
6. Discover what you can about problems in your community concerning

water supplies and land erosion. Find out what factors are related to the problems and how the problems may be solved. Report your findings to the class.

7. Find out what you can about converting salt water to fresh water for large scale use.
8. Using the low power of a microscope, observe samples of clay, silt, and loam in drops of water. Find out how the particle size and composition differ in each soil type.

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CHAPTER 9

Special Adaptations

Every species of plant and animal has adaptations of one kind or another. A simple, green plant cell contains chloroplasts which are adaptations that enable the cell to make foods. A porcupine has barbed quills, which it can use to ward off the attacks of its enemies. A dog that has learned about a skunk's scent glands will probably avoid skunks in the future. Your own hand is a special sort of structure with which you can pick up objects, write a letter, or play a musical instrument. How many other kinds of adaptations can you think of?

Adaptations are of many types, and they aid the organism in adjusting to its environment. Adaptations generally depend upon the presence of certain structures, but do not overlook the fact that behavior is associated with these structures. The subject of adaptation is so broad and so important that two chapters deal with it in this book. In this first chapter, we shall deal with adaptations that relate to survival, obtaining food, flight, and reproduction.

ADAPTATIONS AND SURVIVAL

Even the single-celled forms of life exhibit adaptations that relate to survival. For instance, when environments change, organisms that cannot adjust to the new conditions will die. Many of them do meet the new conditions, and are able to survive when their surroundings are relatively unfavorable.

You should note that an organism cannot develop new structures just because it needs them. If new structures appear, they are the result of hereditary changes in the species. They may or may not prove to be useful changes. But an organism can always use what it already has. For instance, a turtle in a pond that is drying up may walk overland to another pond that still contains water.

Cyst formation. What happens to other organisms when a pond dries up? Are all of the single-celled organisms that live in the pond doomed? By no means, for some of these organisms have the ability to form ***cysts*** (*sists*).

9–1. (A) A single celled organism; (B) the same organism encysted.

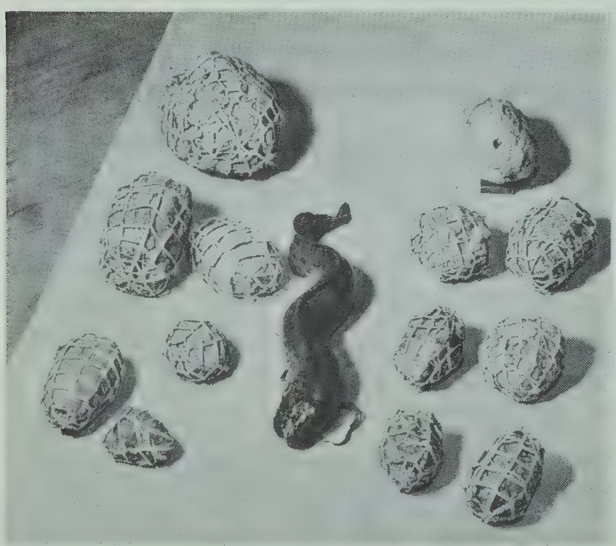
The cyst is a rather heavy covering that is secreted by the tiny organism when water becomes scarce. Usually, the organism loses some of its water content and shrinks to a smaller size, as the cyst is formed around it. The result is shown in Fig. 9–1. Within the cyst, the cell resists further water loss. For the time being, it is leading an inactive life. But if rains come, the cyst will dissolve, and the cell within it will become active again. Or, the cell in its cyst may be carried by the wind to a place where water is available.

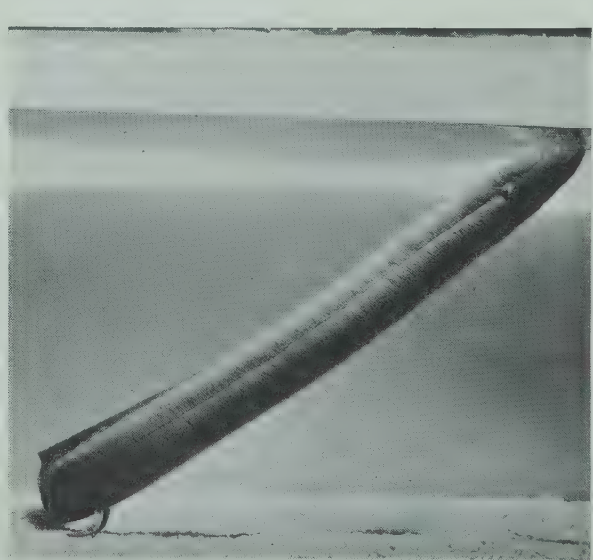
Cyst-formation is by no means limited to single-celled organisms. Some of the invertebrates that have bodies composed of many cells also develop cysts. In these cysts, they pass through resting stages, which may be short in some cases, and long in others.

Spore formation. In a similar manner, certain bacteria form *spores*, when their surroundings become unfavorable. First, a bacterium may contract into an oval or spherical mass. Then a thick membrane, which sometimes is double, is formed around it. Now the bacterium is able to survive under adverse conditions, and may become active again when conditions improve. Spores of this type are something special, and not to be confused with the plant spores that are formed in certain reproductive processes.

Unfavorable conditions that appear to be associated with cyst or spore formation are not limited to lack of water. They also include such factors as high or low temperature, lack of food, and the presence of chemical substances, such as wastes, in the water.

The lungfishes. Even animals as complex as certain fish are able to sur-





9–2. Two types of lungfish. Left, the African lungfish is shipped in these mud-covered cocoons; right, the South American lungfish. (*New York Zoological Society Photo*)

9–3. A striking example of protective coloration is provided by these ptarmigan shown in their summer and winter plumage. (*U.S. Forest Service*)

vive when the pools in which they live dry up. This ability is possessed by the lung fishes. Three species of these fishes live in Africa, one in South America, and one in Australia. They have gills, like other fishes, and under normal conditions they use these gills to obtain oxygen from the water. But they also have *lunglike tissues* in their swim bladders, which can be used to obtain oxygen from air if the need arises.

When the dry season comes and ponds begin to vanish, an African lungfish is able to meet the challenge. It burrows down a foot or more into the mud, and forms a chamber with a small hole at the top. Soon the pond water is all gone, and the lungfish must get oxygen through its lunglike tissues. It lies quietly in its retreat, using stored food reserves, until the rainy season arrives, and the ponds are once more filled with water. Here again we can see how adaptations enable the species to survive during a time when the environment is unfavorable.

Protective coloration and mimicry. Avoiding the attack of natural enemies is important to survival. The rabbit that does not evade the clutches of a hungry fox may be killed. Avoiding hunters, such as a fox, depends to some extent upon not being seen. The grey and brown colors of a rabbit blend well with dead grasses and leaves. Many a rabbit escapes attention just because it cannot be seen. Color patterns of this type represent what is called ***protective coloration.*** Many animals have protective coloration to a greater or lesser extent.

Mimicry (*mimi*-kree) provides protection for some animals. But mimicry involves resemblance in *form* as well as in *coloration.* A walking-stick insect, for example, has a long, slender body that resembles the twig of the bush or tree on which the insect is found. The walking-stick insect's legs might well be smaller twigs extending out at angles. Early in the season, the walking-stick insect is greenish in color when

9–4. The praying mantis blends well with the pine needles. (*Robert C. Hermes from Annan Photo Features*)

9–5. An example of mimicry, the dead-leaf mantid. (*Russ Kinne from Photo Researchers*)

twigs also are greenish. Later on, when the twigs become gray-brown, the walking-stick insect does likewise. You may have passed close by one of these insects a number of times, but failed to see it as distinct from the bush upon which it was resting.

Another striking example of mimicry is provided by the Oriental insect, known as the dead-leaf butterfly. The upper surfaces of its wings are brightly colored, and when the insect is flying you can hardly avoid seeing it. But when it alights on the branch of a tree in a cluster of dead leaves, its wings are folded together and only their undersides are visible. Now the story is very different, for the undersides of the wings resemble a dead leaf to perfection. They even have color lines on them that look like the veins and branch veins of a leaf. It seems probable that a dead-leaf butterfly thus escapes the attention of a good many insect-eating birds.

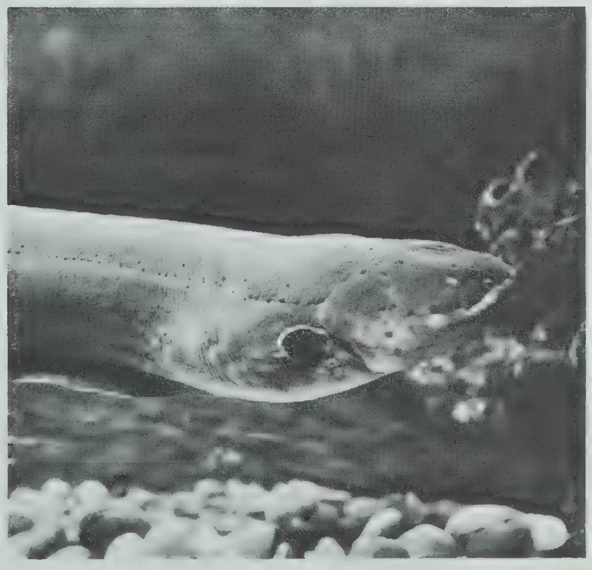
An ink-screen defense. Among the mollusks of the sea there are two types that have a novel way of escaping from their enemies. They are the squids and the octopuses. Squids are elongated, and have ten arms bearing sucking discs. Octopuses are more compact in form, and have eight arms. In the bodies of both types are ink sacs which contain a dark-colored fluid. If one of these animals is threatened, it may discharge a quantity of ink, and then swim away while hidden by its "ink screen."

Squids also exhibit an interesting type of coloration. In their body walls are a variety of pigment spots, which apparently can contract and expand. As a result, a squid can change color quite rapidly. It generally assumes a color that resembles its surroundings, and therefore tends to be concealed.

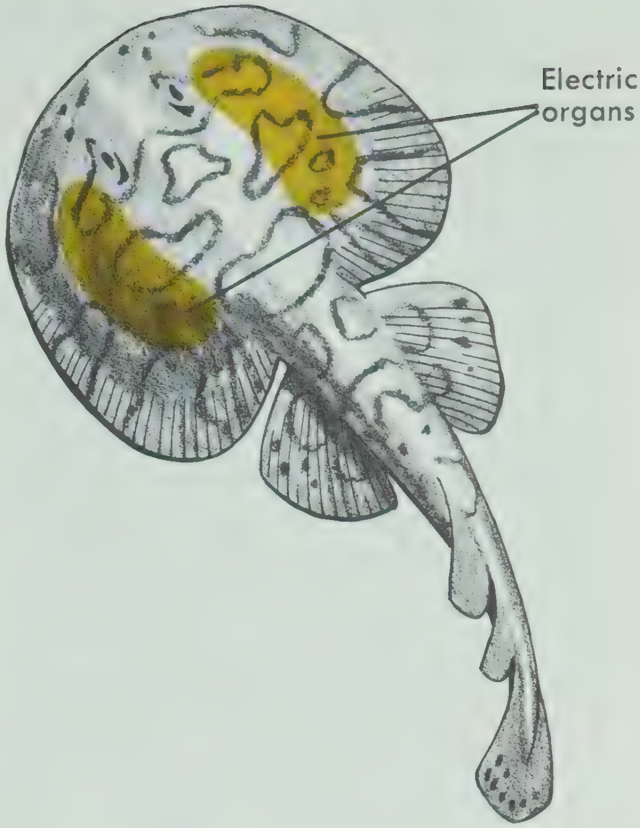
Animals with electric organs. A number of different animals develop structures that we call *electric organs.* Such an organ consists of special cells that generate electric charges. The charge produced by a single cell is small, but some electric organs contain almost a half million cells, and their combined output is considerable. An electric organ must, of course, hold its charge just as a battery does, and then deliver the charge when need arises.

The *electric catfish,* which lives in streams of Central and North Africa, is a fairly large fish that has such electric organs. Studies have shown that it can develop a current of about 100 volts. You can compare this with the electric current we use in our homes, which is often about 120 volts. Like other animals that have such organs, the electric catfish uses them for two purposes: to ward off the attacks of enemies, and to paralyze animals that will serve as food.

The *electric eel* of the Amazon River Basin in South America probably has the most effective electric organ. It is a large structure extending along the upper surface of the eel's body. It can deliver an electric discharge of about 600 volts. This is enough to disable animals as large as horses and cattle.



9–6. An electric eel. (*Russ Kinne from Photo Researchers*)



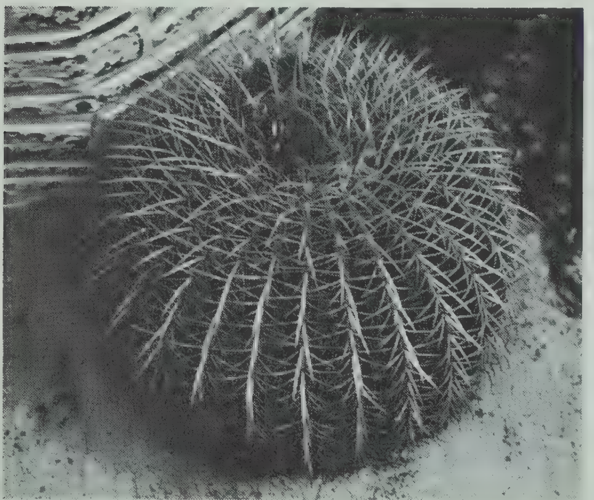
9–7. A torpedo ray.

In the warmer seas, animals known as *torpedo rays* also possess electric organs. These torpedo rays are related to the sharks, but hardly look the part, because of their flattened form. Figure 9–7 shows a torpedo ray with its two electric organs on the upper side of the body. Some other species of rays have no electric organs, but have other defenses that can be very effective. The *sting rays,* for instance, have a single saw-toothed spine on their whiplike tails. In some species the spine is coated with poison from a poison gland. The *sea bat* is a very large ray that few other animals will attack. It is not unusual for a sea bat to weigh over a ton.

Adaptations of desert plants. Even though you may not have visited a desert, you know that it is a land of little rainfall. Desert temperatures may vary greatly from time to time. Deserts may also be subjected to intense sunlight and strong, dry winds. Such conditions are unfavorable for many plants and animals.

One of the major problems facing desert organisms is that of obtaining and holding water. But the green desert shrub called mesquite has roots that are up to 100 feet long. These roots can reach down to a water table that is far below the surface. Other desert plants, like the barrel cactus, have shallow, but very widespread root systems. Following a rain, large amounts of water can be absorbed by such roots and this water can be stored in special stem tissues of the cactus plant.

The leaves of desert plants also are adapted to life in a dry environment. Leaves normally lose water to the air through their stomata. But desert plants generally have small leaves, or are leafless, like members of the cactus family. Any reduction in leaf surface, of course, tends to lessen water loss.



9–8. The barrel cactus has a widespread root system that can absorb great amounts of water. (*E. Tamiso from Photo Researchers*)

The seeds of some desert plants sprout only after the winter rains. Now the plants grow rapidly, produce flowers and seeds, and die. Plants like these are active only when soil moisture is available. They survive the summer drought in the form of seeds. These seeds will not sprout until adequate rain falls.

ADAPTATIONS OF A SNAIL

If you observe a snail carefully, you will discover various ways in which it is adapted to survive. You can keep a land snail in a moist terrarium or battery jar, and feed it small pieces of lettuce. An aquatic snail may be kept in an aquarium or a jar of pond water that contains some plants.

OBSERVING A SNAIL'S BEHAVIOR Examine your snail's structures and observe the things that it does. Identify the ways in which it is adapted to move from place to place, locate food, eat food, and protect itself. See if you can find out how the snail uses its tentacles. Touch the snail gently and observe how it responds.

SURVIVAL WHEN IN A DRY ENVIRONMENT Ponds sometimes dry up, and aquatic snails must adapt to the change or die. Do aquatic snails have adaptations which aid them under such circumstances? If so, are body parts involved, or patterns of behavior, or both?

Try putting a pond snail in a dry battery jar covered with a screen. Keep it in a cool, dry place overnight, and observe it the next day. Then return the snail to the water and see how it responds.

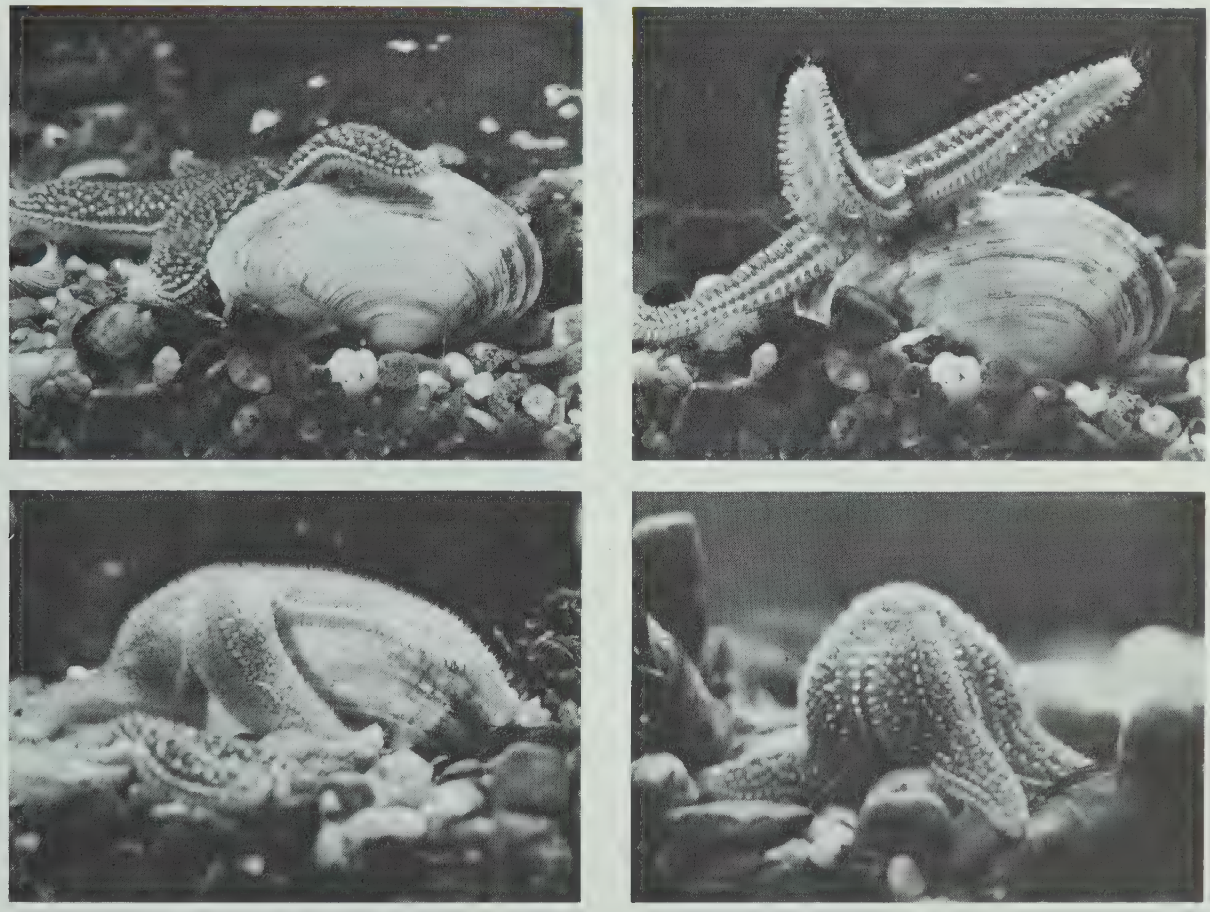
ANALYSIS Prepare answers to the following questions in your notebook:

1. Was your snail adapted for eating plant food, or animal food, or both types? What evidences do you have?
2. In what ways was your snail adapted to move about? Locate food? Protect itself?
3. How was your pond snail adapted to survive out of water?

ADAPTATIONS AND FOOD

There are many adaptations that are related to obtaining food. Such adaptations are, of course, factors in survival, because obtaining adequate food supplies is essential to the well-being of plants and animals.

A starfish eats a clam. One of the striking adaptations for obtaining food is possessed by the starfishes. Starfishes are common along various sea coasts, and they often prey upon clams and oysters. The clams, of course, have hard outer shells, each shell being made up of two parts or valves that can be clamped together. When the clam is threatened by a natural enemy, it closes its shell, and thus protects the soft, fleshy parts that lie within the shell.



9–9. This sequence of pictures shows the slow process of how a starfish attacks and eats a clam. (*Charles Wolcott*)

But such a defense is no defense at all against a starfish. On the undersides of its arms, a starfish has rows of little structures called *tube feet*. The starfish attaches these tube feet to the outside of the clam shell, and begins to pull the two valves of the clam apart. At first, the clam does not yield, but the starfish keeps right on trying, and sooner or later the clam shell opens.

Now the starfish performs another unusual act. If it lets go of the clam at this point, the clam shell will promptly close. But the starfish does not let go. In the central part of its body mass, the starfish has a pouchlike stomach. The starfish forces this stomach out through its mouth opening, and wraps it around the fleshy part of the clam. Soon the clam is partly digested, and the stomach, together with its newly acquired food contents, is drawn back into the body of the starfish.

A deep-sea angler. Another odd type of animal is the deep-sea angler shown in Fig. 9–10. Clearly, this is a fish that preys upon other animals of the deep. Notice its very large mouth, and a number of large, pointed teeth.

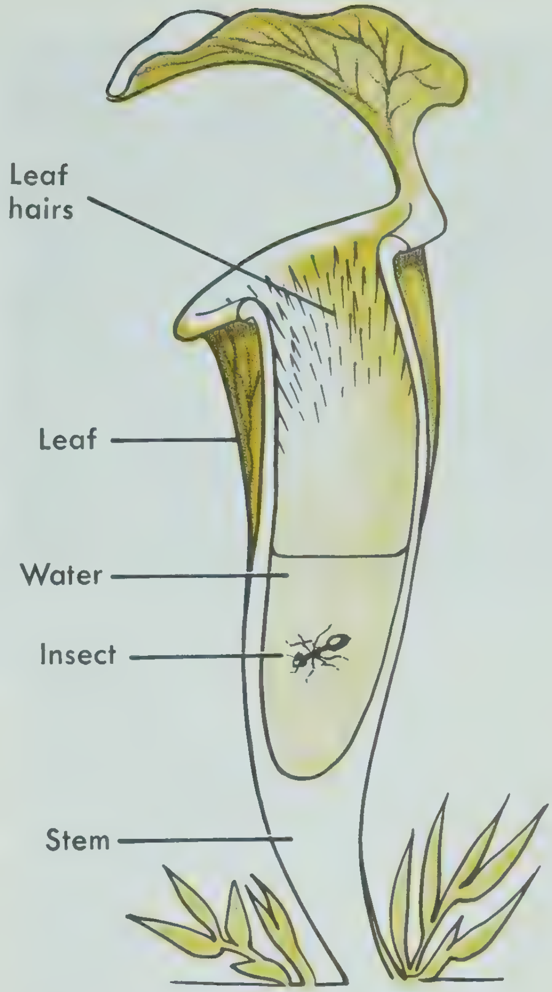
Like various other animals that live in dark waters far beneath the surface, the deep-sea angler has *luminous* or light-producing organs. One of these is a sort of "headlight" that projects outward from the animal's upper jaw. Another is a branching "lure," that hangs down from the lower jaw. It is believed that these luminous parts serve to attract other animals within easy reach of the angler's murderous teeth.

Plants that are carnivorous. We generally think of our land plants as species that make their own foods. And for the most part they do so. But pitcher plants supplement their food supplies with the proteins of insects and other small animals. So they are sometimes said to be carnivorous plants.

You generally find pitcher plants growing on very moist soil in bogs. Their green leaves take the form of elongated cups or pitchers, with openings at the top, as shown in Fig. 9–11. Near the top of the leaf are hairlike processes that slant downward. When an insect falls into the cavity within a leaf, it is not likely to get out again, because these hairs block its way. Moreover, the insect falls into the water which fills a considerable part of the "pitcher."

The water within the "pitcher" contains digestive *enzymes* that have been secreted by certain cells of the leaf. So the small animal victim is digested in

9–10. A deep-sea angler fish.



9–11. A carnivorous plant, the pitcher plant. (*W. H. Hodge*)

this water. Later, the digested food materials are absorbed into leaf cells.

Pitcher plants are not the only higher plants that make use of animal foods. The sundews and Venus's-flytraps, which also grow on marshy soils, digest animal tissues in similar fashion. In fact, about 500 different kinds of plants are carnivorous.

Teeth and foods. You generally can tell what sort of food an animal eats by examining its teeth. A squirrel, for instance, eats various hard plant materials such as nuts and acorns. It also hollows out cavities in trees to make secure retreats. The squirrel can do these things because it has a special kind of teeth.

If you examine the skull of a squirrel, you will find four large, chisel-

9–12. The Venus's-flytrap with its insect victim. (*Hugh Spencer*)

9–13. The large incisor teeth of a woodchuck or groundhog. (*Grant Heilman*)

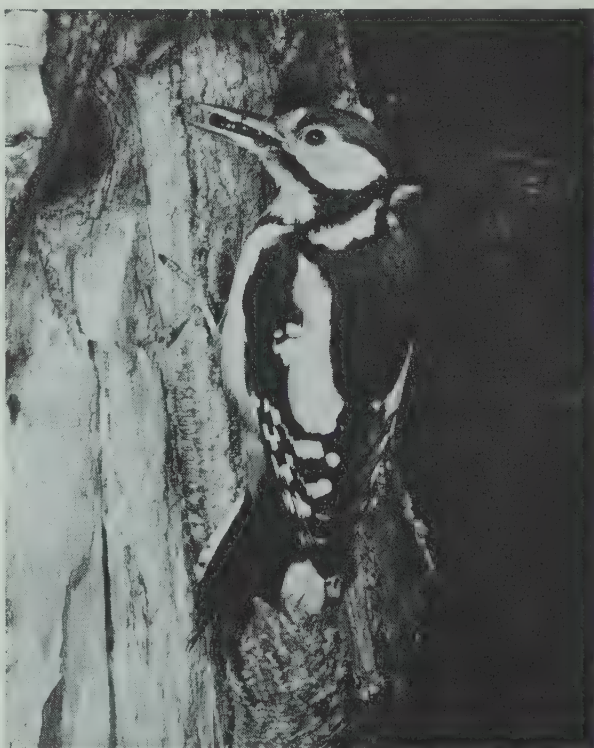
shaped teeth out in front. These are the ***incisor*** (*in*-cizor) teeth: two in the upper jaw, and two opposite them in the lower jaw. These teeth serve to gnaw through hard, woody fiber. Behind them there is a gap, and then some teeth in the back of the mouth. These back teeth are used to chew plant materials.

A squirrel's teeth are good equipment for eating nuts and acorns. Its incisor teeth are unusual because they continue to grow throughout life. Their *chisel-like* ends wear off as the squirrel gnaws, but since these teeth are always growing, they do not become worn down as a dog's teeth would.

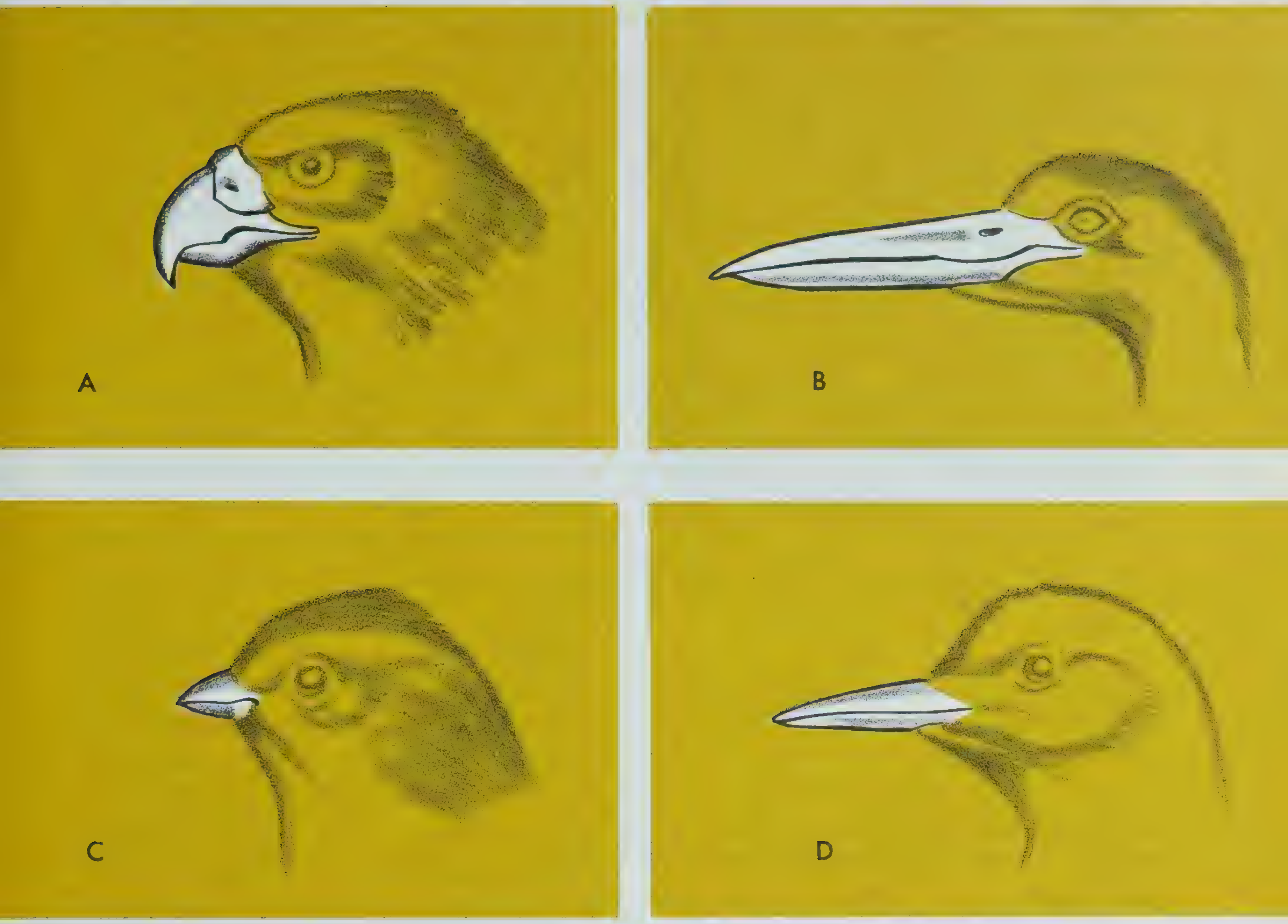
Now if you look at a cat's skull you will see teeth that are very different. A cat is descended from a long line of flesh-eating ancestors. Its teeth are of the flesh-eating type. In front are the cat's incisor teeth, but they are relatively small. The teeth used in grasping prey are the long, pointed ***canine*** (*kay*-nine) teeth; one above and one below, on each side of the head. The cat's back teeth have *shearing* surfaces that are useful in cutting up flesh before it is swallowed.

Squirrel teeth and cat teeth are adapted to eating rather special types of food. Some other animals have teeth that serve to chew a variety of foods. Our own teeth, for example, are not the nut-cracking or meat-shearing type, but they can be used to chew many plant and animal tissues.

The bills of birds. The bills of our common birds may also indicate the type of food that is eaten. Some of these bills are shown in Fig. 9–15. Hawks and owls have bills that curve downward to form a sharp point used in tearing the flesh of prey. They also have powerful feet and claws that can be used to grasp their victims. On the other hand, a heron's bill is a spear-shaped device that is adapted for seizing frogs and small fish. A seed-eating bird, such as



9–14. The great spotted woodpecker ferreting out insects from the bark of a tree. (*Hermann Schunemann from Annan Photo Features*)



9–15. Bird bills are adapted to the type of food they eat. (A) The curved bill of a flesh-eating bird; (B) the spear-shaped bill of a fish-eating bird; (C) the short bill of a seed-eating bird; (D) the chisel-like bill of an insect-eating woodpecker.

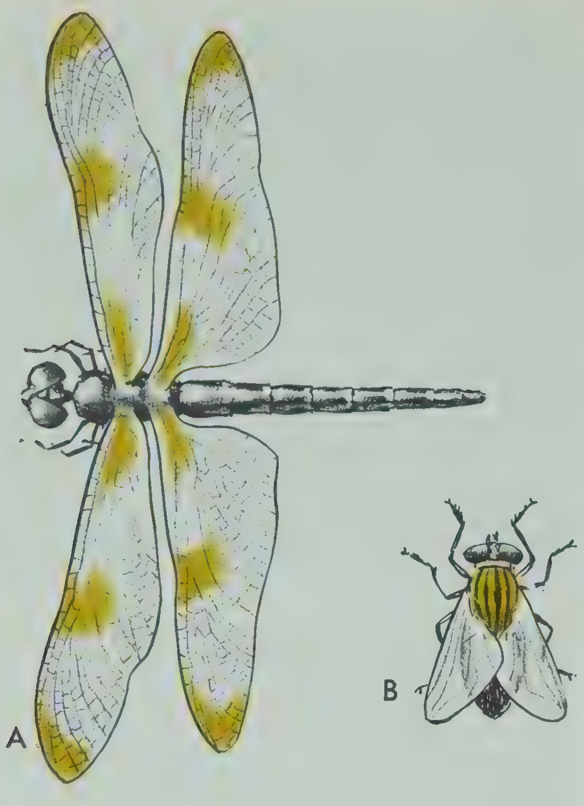
a sparrow, has a short, powerful bill that is heavy at its base. A woodpecker has a chisel-like bill that can be used to ferret out insects in the bark of trees.

ADAPTATIONS FOR FLIGHT

The fossil record tells us that the earliest forms of life lived in the seas. Millions of years later, some plants and some animals developed adaptations that made life on land possible. At some other time in the distant past, living things began to fly.

We naturally think that an organism must fly if it is to exist in the air. But this is not always the case. In the air, you find vast numbers of bacteria, cysts, spores, pollen grains, and other small organisms or products of organisms. Even spiders riding portions of their webs may appear far above the earth's surface. Small organisms of these types have been found in air samples taken at a height of several miles. They have even appeared in air samples taken above oceans.

Insect flight. Probably, the first animals that could really fly were some large insects that lived in swamps



9–16. An example of a four-winged insect (A-dragonfly) and a two-winged insect (B-housefly).

about 500 million years ago. Their descendants are still with us today. In fact, insects make up the largest modern animal group. Among the adaptations that have made them successful is the ability to fly.

Some present-day insects have no wings, but these species are the exception. The great majority of insects either have two wings or four wings. These wings are quite unlike the wings of birds, even though they serve the same general purpose. Figure 9–16 shows examples of two-winged and four-winged insects.

An insect's body has a hard outer covering or skeleton. The body is divided into a head, a thorax, and an abdomen, as described on page 243. In the region of the thorax, portions of the external skeleton grow outward, and become flattened to form the wings. These wings are operated by muscles inside the body. In a small animal this arrangement works quite well, although an insect is handicapped in cold weather because it is cold-blooded.

An unusual feature of an insect's wing is the way it is supported. Within its body, an insect has branching tubes which connect with pores or openings on the sides of the body. These tubes serve to bring oxygen to the body cells, and to carry away carbon dioxide waste. When an insect's wings develop, some of these tubes grow out into them, and form the veins that run from the base of a wing to its outer end.

You should note that an insect's wings have nothing to do with its three pairs of legs. An insect's wings are modified parts of the external skeleton and the animal's respiratory system.

The flight of birds. Birds have feathers, which are really modified scales. They inherited these scales from their ancestors, which were reptiles that lived millions of years ago. A few bird species are flightless, but many other species are at home in the air.

9–17. The common tern is very graceful in flight. (*Walter Dawn*)

Bird wings are modified front limbs, covered with feathers. Wings, however, are only part of the story of flight. For flight requires great muscular exertion, and a bird has other adaptations that make this type of muscular effort possible. For one thing, the flight muscles in the shoulder region are powerful. The bird's skeleton provides good attachment and support for these muscles. Moreover, this is not done at the cost of adding weight. A bird's long bones are hollow. Various bones, especially in the head and back regions are light in weight, but give good protection and support, because they are firmly joined to other bones.

A bird has two lungs just as we do. But it also has *air sacs* which connect with the lungs. In some birds, the air sacs extend into the hollow long bones. These air sacs do not contain lung tissue, but they can supply the lungs with fresh air when a bird exhales. They also are spaces into which excess body heat may be discharged. A good oxygen supply is, of course, necessary to support the exertion of flight.

We may also note that a bird is warm-blooded, and is able to supply energy for work at a rapid rate. So a bird has an advantage that an insect does not possess. An insect's muscle responses slow down when the weather is cold.

The flight of bats. Flying squirrels can glide through the air from a higher point to a lower point. But bats are the only mammals that can really fly. You may have heard about "flying foxes," but do not let the name mislead you. Flying foxes are fruit-eating bats that live in the Orient. Some of them have a wing spread of about five feet.

A bat's wings are supported largely by its front limbs. But the flying membrane extends back to the hind limbs and the rather short tail. The covering of this membrane is the bat's skin layer. Bats are capable of sustained flight.

9–18. The little brown bat. (*Rue from Monkmeyer*)

Our North American bats are small insect-eating species. Perhaps you have seen one of these bats zig-zagging about in the air at dusk. Its motions have a purpose. The bat is hard at work feeding upon flying insects. You may also have heard a bat uttering high-pitched squeaks while in flight. Actually, the bat utters these shrill cries all the time it is in the air. Most of these cries are so high in pitch that the human ear will not detect them.

This bat habit of constantly calling out while in flight is not due to fear or a nervous nature. The cries serve a very useful purpose, because they are echoed back from solid objects. Thus, the bat is warned when it is about to collide with something. It changes course at once, moving away from the danger spot. A bat can fly about in a darkened cave or barn without injury to itself.

Being insect eaters, our North American bats are useful. They are not "blind as a bat," but can see better than we do in dim light. In spite of stories to the contrary, they do not carry bedbugs, or alight on women's heads to tear at their hair. They do have some odd habits, such as attaching themselves by their hind claws and hanging head downward, when they are resting or sleeping.

The vampire bats, which are found in tropical parts of Central and South America, are bloodeaters. They use their teeth to make shallow cuts in the skins of sleeping animals. When the blood flows, the bats lick it up. They do not hesitate to take blood from a sleeping man, if they have the chance. Domesticated animals are annoyed and sometimes injured by these attacks. The real danger is due to the fact that these bats carry certain diseases.

THE BIRD SKELETON

You may have a chance to examine a mounted bird skeleton. If possible, compare it with the skeleton of a mammal, such as a cat, or a rat, or with a chart of the human skeleton. One important function of a skeleton is to provide places of attachment for the muscles that move the body.

THE SHOULDER GIRDLE The front limb of a bird or a mammal is attached to the bones of the *shoulder girdle.* In man or any other mammal, this girdle consists of only two bones on each side of the body. A *collar bone,* which is fastened to the upper end of the *breast bone,* extends out to the point of the shoulder. Here it meets a *shoulder bone,* which is merely supported in place by the muscles of the back. Locate these structures of a mammals skeleton. See how the bone of the upper arm joins the shoulder girdle.

Now compare what you have seen with the shoulder girdle of a bird. Right away, you see that the bird's shoulder is supported by *three* bones. It has a collar bone and a shoulder bone. In addition, a third bone extends down from the point of the shoulder to the breast bone. This extra bone gives the shoulder girdle much firmer support. Note also that a bird's breast bone is much larger than the breast bone of a mammal. It bears a bladelike *keel,* to which many flight muscles are attached.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Of what benefit is a lightweight skeleton to a bird?
2. In a few birds species the breast bone has no keel. What kinds of birds do you suppose these are?

ADAPTATIONS AND REPRODUCTION

Many rather striking adaptations relate to the manner in which plants and animals reproduce. Some of them are adaptations of behavior, such as the travels certain fish undertake, when they are about to spawn, or lay their eggs.

West coast salmon runs. Several species of salmon, found along the West Coast of North America, engage in what

are called salmon runs. These runs are journeys for the purpose of laying eggs. The salmon live in the sea most of their lives, but every year some adult males and females gather in bays where West Coast rivers empty into the sea. Then a journey upstream begins. The fish must make their way through rapids and long reaches of swiftly flowing water. In some cases, they swim a distance of about a thousand miles.

Finally, the salmon reach quiet pools at the headwaters of the streams they have ascended. Here the females lay eggs on the gravelly bottoms, and the males fertilize the eggs. Due to lack of food, exertion, and injuries, the adult salmon appear to be worn out at this point, and they generally die. In due course, young salmon are hatched, and begin a gradual descent of the rivers back to the sea. Some young fish may reach the sea about six months later. Now they become ocean dwellers for several years, or until it is time for them to engage in a run of their own.

Some other fish adaptations. Other species of salmon are found in the Atlantic Ocean, and make journeys up East Coast rivers of Canada to lay their eggs. The American eel, however, is a freshwater species that spawns in the sea. It spends most of its life in the streams and lakes of eastern North America. But each year some mature eels leave their freshwater homes and descend rivers to the sea. They then travel to a deep area of the Sargasso Sea off the West Indies, where they lay their eggs. The adults do not return to fresh water again.

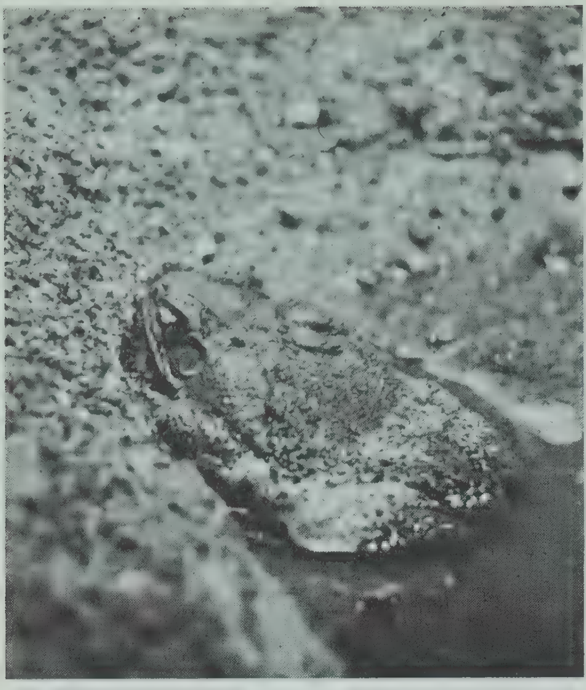
When the eel eggs hatch, the young fish that come from them do not look much like eels. At first, they are not long and snakelike. They soon begin to swim back toward North America, and

9–19. Salmon going upstream to lay their eggs. (*Thompson from Annan Photo Features*)

it may take them a year or more to complete the long journey. Meanwhile, their bodies lengthen and become eel-like. Now they ascend rivers to the freshwater habitats from which their parents came.

There also is a European species of eel which is similar to the American type. Oddly enough, European eels travel to the same location in the Atlantic Ocean to do their spawning. This is a very long journey, and it may take a young eel three years to go from the spawning ground to European shores.

Sea horses have a different sort of adaptation that is related to reproduction. The brood pouch is of special interest. This pouch is developed by the *male* sea horse at the point where the tail joins the body. The female sea horse deposits her eggs in this brood pouch. Then the male acts as custodian of the eggs until they have hatched.



9–20. The female Surinam toad with eggs on her back. (*R. Freund from Photo Researchers*)

Surinam toads. The Surinam toads are South American species that manage to produce young without returning to ponds to lay eggs. Most female frogs and toads deposit their eggs in the water. From these eggs come tadpoles, which will later develop into adults that can live on the land.

When a female Surinam toad produces her eggs, they are promptly spread over the spongy skin on her back. A small cavity develops around each egg, the egg sinks into the cavity, and a sort of lid is formed over the egg. In time, most of the eggs hatch, and tadpoles come from them. These tadpoles stay right in the skin "pockets" for the time being. When they finally emerge, they are young adults, and able to live on the land.

WORD MEANINGS

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. An adaptation might be (a) a part that protects an organism; (b) a special color pattern; (c) a way of behaving; (d) all of these.
2. The function of cysts is most closely related to (a) survival; (b) mimicry; (c) protective coloration; (d) defense.
3. Lung fish can obtain oxygen only by means of (a) gills; (b) lungs; (c) gills and swim bladders; (d) lungs and swim bladders.
4. An example of mimicry is (a) the color of a rabbit blending with grass; (b) a walking-stick insect resembling a twig; (c) the ink screen of an octopus; (d) a starfish eating a clam.
5. Electric organs are structures found in certain species of (a) toads; (b) insects; (c) rays; (d) mammals.
6. Tube feet are structures developed by (a) starfishes; (b) clams; (c) squids; (d) pitcher plants.
7. A carnivorous plant is one that (a) cannot make food because it lacks chlorophyll; (b) can make food, but also feeds on small animals; (c) lives entirely on food it gets from insect bodies; (d) should be classified as an animal.

8. Canine teeth are adapted to (a) gnaw hard materials; (b) cut flesh into smaller pieces; (c) hold prey; (d) grind up plant materials.
9. In the following list, the animal that has a keel on its breast bone is a(n) (a) insect; (b) bird; (c) amphibian; (d) mammal.
10. All insects, birds, and bats are (a) able to fly; (b) warm-blooded; (c) cold-blooded; (d) animals.
11. Eels are (a) like salmon in that they lay eggs in fresh water; (b) not fish; (c) found only in North America; (d) freshwater fish that spawn in the sea.
12. The Surinam toad (a) lays its eggs in pond water; (b) carries its young in skin "pockets"; (c) is actually a reptile; (d) is commonly found in North America.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The human hand is an adaptation for picking up and holding objects.
2. Organisms that are unable to adjust to changing conditions are unlikely to survive.
3. Cyst formation is found only among single-celled animals.
4. Bacterial spores may be formed in response to a change in temperature, as well as to a lack of water.
5. Lungfishes lack gills.
6. When its pond dries up, a lungfish will make its way across land in search of another pond.
7. The dead-leaf butterfly provides an example of mimicry.
8. Octopuses have eight arms with sucking discs, while squids have ten.
9. Octopuses can change color rapidly, but squids cannot.
10. A starfish can force its stomach out through its mouth opening.
11. Only three kinds of carnivorous plants are known.
12. Chisel-shaped front teeth used for gnawing are called incisors.
13. A squirrel's gnawing teeth grow throughout its life.
14. A bird with a bill that curves downward to form a sharp point is probably a seed-eating bird.
15. Various bacteria and cysts are found in the air above the earth's surface.
16. All modern species of insects are able to fly.
17. An insect's wing is developed from structures of the external skeleton and the respiratory system.

18. The feathers of a bird represent modified scales.
19. In terms of a bird's size, its skeleton is unusually heavy.
20. The flying ability of birds is hampered by the fact that they are cold-blooded.
21. Our North American bats are largely fruit-eating species.
22. Vampire bats are species that feed on the blood of other animals.
23. A bird has an unusually well supported shoulder girdle.
24. During a salmon run, adult fish move from the sea into freshwater streams.
25. The American eel spends most of its life in freshwater streams and lakes.
26. The American eel and the European eel both lay their eggs in the same part of the Atlantic Ocean.
27. The female sea horse carries her young in a brood pouch.

DISCUSSION QUESTIONS

1. In what ways are you specially adapted to your environment?
2. What is meant by the statement, "All plants and animals possess adaptations"? What kind of evidence would be needed to support such a statement?
3. In what ways are organisms adapted to drying conditions? Give examples.
4. In what ways are organisms adapted to cold conditions? Give examples.
5. What is the difference between protective coloration and mimicry?
6. In what ways are organisms adapted to protect themselves by hiding? Give examples.
7. How do the adaptations of starfish enable them to overcome the protective adaptations of clams?
8. In what ways is a pitcher plant adapted to obtain animal food?
9. Explain what is meant by the statement, "You can tell what sort of food an animal eats by examining its teeth."
10. In what ways are the different teeth in your mouth adapted to perform special tasks?
11. How are different kinds of birds adapted to obtain and eat different kinds of food? Give examples.
12. What kinds of organisms inhabit the air?
13. From what structures are an insect's wings developed?
14. How does a bird's wing differ from an insect's wing? From a bat's wing?
15. In what ways is a bird skeleton well adapted for flight?
16. What are air sacs, and how are they related to flight?

17. Can you think of any way in which air sacs might be useful to an aquatic bird? Explain.
18. What structures are modified to form the wings of bats?
19. How does a bat avoid colliding with solid objects when it is flying at night?
20. What environmental problems would eels encounter, as they move from fresh water into the sea?

THINGS TO DO

1. Obtain a small bit of soil from the surface of a dry pond or lake. Test the sample for the presence of living things, adapted to drying conditions, by placing the soil in a few hundred milliliters of tap water. Keep the water and soil mixture in a flask with a cotton stopper. Put the sample in a cool, lighted place, and observe it each day for the presence of living things. Check a sample of the water from time to time with a microscope. How can you be sure that any living things that appear came from the soil and not from the tap water?
2. Prepare bulletin board displays to illustrate the ideas of protective coloration and mimicry. Use sketches, pictures, or actual specimens in your displays.
3. If specimens are available, examine the teeth of mammals and the bills of birds of various kinds. See if you can determine what kind of food each animal is adapted to eating. Check your answers by using reference books. If specimens are not available, you may be able to carry on a similar study using pictures of birds and mammals.
4. Compare the structures of two long bones: one from a mammal, and the other from a chicken. Use a hack saw to make cross sections of the bones. Observe the presence or absence of hollow interiors.
5. Using references, prepare a report for the class on one of the following topics: spore-forming bacteria; adaptations to the deep sea environment; carnivorous plants; aquatic insects; life in the air.

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CHAPTER 10

Patterns of Behavior

By this time, you realize that in one way or another adaptations make it easier for organisms to survive. In all cases, these adaptations depend upon certain structures of the organism. But often the more striking feature is what the organism *does* with the structures. This is *behavior*. In this chapter, you will read about adaptations that feature behavior.

HIBERNATION

A large number of small animals do not survive the cold blasts of winter. But some do survive, because they are sheltered in one way or another. They may be in water beneath the ice, or in burrows or other retreats down in the soil. Some of them are able to become largely inactive during cold periods. They resume normal activity when the environment becomes favorable again.

Some animals hibernate. In cold areas, some of the animals ***hibernate*** (*hyber*-nayt) during the winter season. A leopard frog, for example, burrows down into the mud at the bottom of a pond, and stays there until the following spring. Of course, it must be in a place where the mud and water do not actually freeze.

While this frog is hibernating, its life processes go on, but at a reduced rate. The animal gets energy from food that is stored in special *fat bodies.* It cannot use its lungs, but gets enough oxygen from the water through blood vessels in its skin. When the frog becomes active again in the spring, it is lean and hungry, and its fat bodies are much reduced in size.

Some warm-blooded animals also hibernate. They include certain bats, certain mice, and several species of woodchucks and ground squirrels. Generally, these animals build up a reserve supply of fat in autumn. This fat is very necessary, for some of these animals lose almost half of their body weight before the winter has passed.

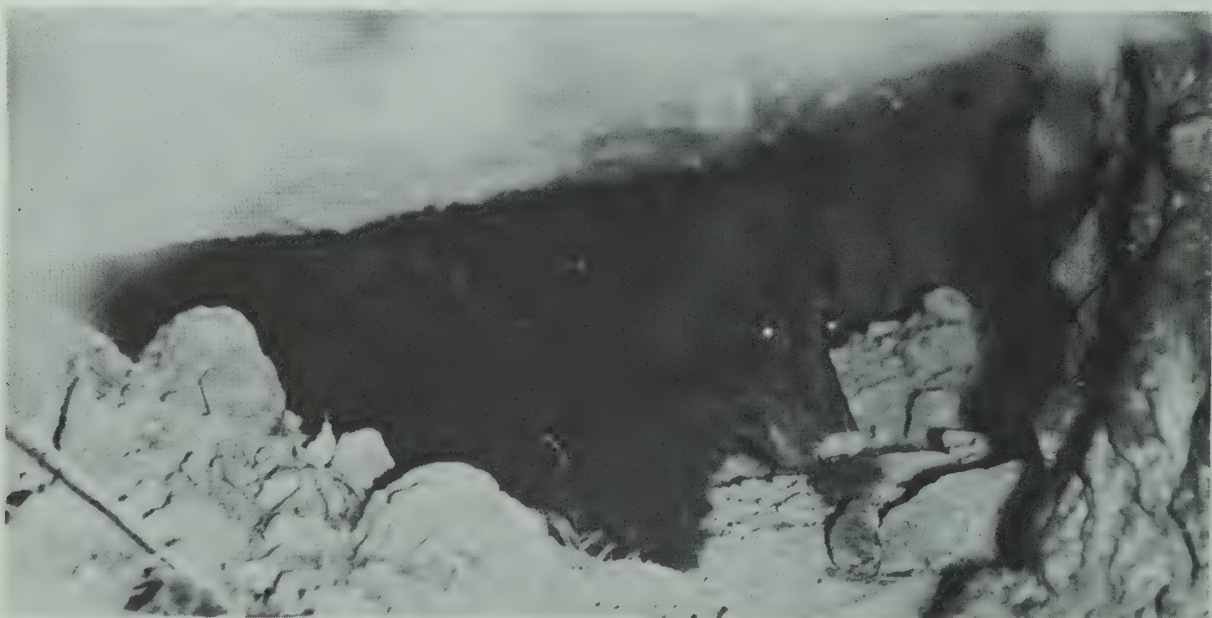
A ground squirrel that is ready to hibernate goes down into its burrow to

10–1. The leopard frog hibernates during the winter. (*Karl H. Maslowski from Photo Researchers*)

10–2. The hibernating posture of the chipmunk. (*John H. Gerard from National Audubon Society*)

a simple little nest of dried grass that has been prepared in advance. It blocks off its retreat with a small amount of loosely-packed earth. It may do this while the weather is still warm, and while plenty of food is to be had above ground. The ground squirrel curls up in its nest, and passes into a *torpid* condition that will last until the following spring. Its breathing rate falls to a very low level and so does its heart beat rate. Its body temperature is about that of its surroundings, and this may be only a little above freezing. Life goes on, but in a greatly reduced fashion.

Woodchucks hibernate in much the same way as ground squirrels. While they are torpid their life processes



10–3. This bear does not really hibernate, but spends long periods of time sleeping during the winter months. (*Russ Kinne from Photo Researchers*)

proceed very slowly, and they remain this way until spring has come again. In very cold weather, such animals as chipmunks, squirrels, raccoons, and skunks also remain in their dens, but they are not truly hibernating. When there are mild winter days and nights, these animals promptly come out of their retreats.

MIGRATION AND EMIGRATION

When we talk about animals that ***migrate*** (*my*-grate) our thoughts naturally turn to birds. To migrate means to engage in seasonal travels between summer and winter homes. Many birds migrate, and so do some mammals. To ***emigrate*** (*emuh*-grate) means to move from one place to another place; in other words, there is no return journey except as a result of chance or accident.

Migrations of birds. In our country it is a common experience to see flocks of birds on their way south in the autumn, and on their way north in the spring. Some of the birds engage in very extended travels; for instance, the arctic tern. Terns are birds found along sea coasts, and the arctic tern is a species that travels back and forth between the Arctic Circle and the Antarctic Circle, making an annual journey of over 20,000 miles.

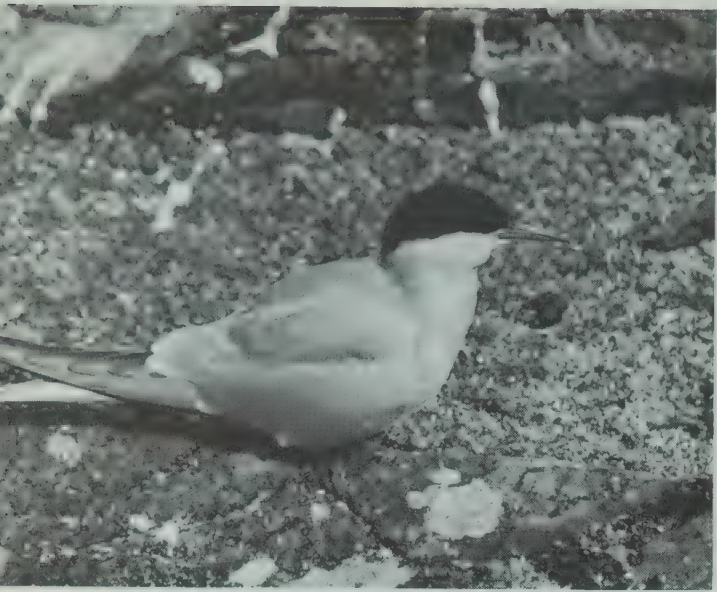
Another bird that engages in a very long migration is the golden plover, whose summer home is along Arctic beaches. In autumn, the members of this species move eastward to the region of Labrador in Canada. Then they take off southward across a portion of the Atlantic Ocean, and may fly as far as the West Indies on this leg of their journey. They continue on down

10–4. Great flocks of geese and ducks during the fall migration. (*Irving B. Lincoln from Photo Researchers*)

to their winter home in the southern part of South America. In the spring, these plovers follow quite a different route which takes them over Central America and up the Mississippi Valley on their way back to the Arctic. When they reach their nesting grounds again, the plovers have completed a round trip of about 15,000 miles.

Many other birds migrate, but most of them do not travel as far as the arctic tern and the golden plover. In fact, some of the migrations are fairly short, and various birds do not migrate at all. There are also cases in which birds migrate from east to west, rather than from north to south.

One of the more puzzling questions of bird migration is, "How do they find their way?" This is particularly true in the case of species that make long flights across the open sea, where there are no landmarks that might guide



10–5. The artic tern (left) and the golden plover (right) both make annual journeys of over 15,000 miles. (*Left, Roger Peterson from Photo Researchers; right, Charles J. Ott from National Audubon Society*)

them. Yet these birds arrive at their destinations more or less on time, provided they have not been blown off course by severe storms. There is evidence that some birds, which migrate by day, orient themselves to the position of the sun and also, that some birds which travel at night use the positions of the stars as guides. But details of this performance remain a mystery.

One of nature's puzzles. Although we have a fairly good idea of *how* birds travel back and forth, there is still the question of *why* they do this. Why do so many bird species move far to the south in the autumn, and return north the following spring?

There are various theories that attempt to explain bird migration. One idea is that birds developed the habit during the last great Ice Age. Winter advances of snow and ice sheets drove them southward, but they returned to the north each summer, when some of the snow and ice melted. Another theory is that birds go south in the winter because food supplies are scarce in northern lands. Certainly, ponds freeze over, snow covers seeds on the ground, and many insects have been killed by the cold. But on the other hand, a large number of birds start south in late summer before the frosts. They leave their northern homes at a time when food is abundant.

You can also ask why birds leave the tropics in the spring and come north again. One theory holds that increased day length leads to greater bird activity. At the same time, the birds' sex organs become larger. Perhaps this stimulates the birds to embark on the northward journey. But do not overlook the fact that in tropical areas day length is about the same the year round.

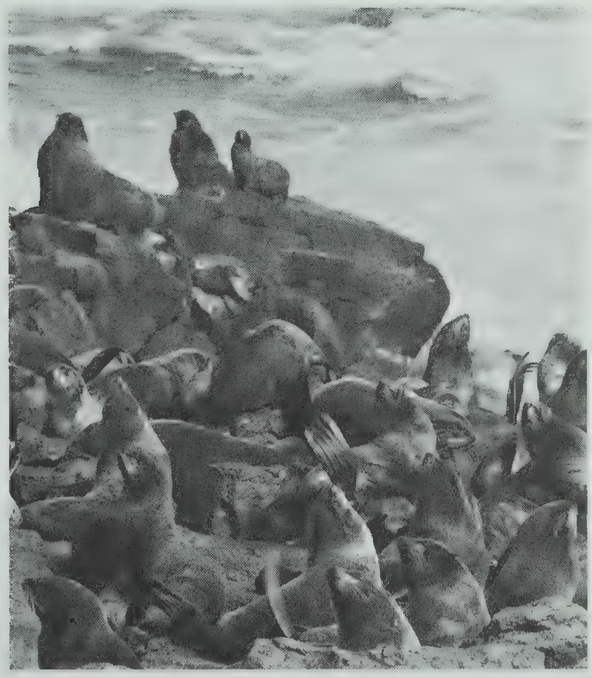
Probably some advantage is gained by nesting north of the tropics. In northern countries bird families are spread out over a wide area, and there is less competition. Each family can have a fairly large territory, which will supply food for both adults and young. Even the birds that stay in the tropics

may profit when other birds fly north. They too will have less competition.

As you can see from this account, there is no ready answer to the question, "Why do birds migrate?" It is quite possible that there is more than one cause for this type of behavior.

Mammals that migrate. The fur seal is a good example of a mammal that migrates. Its summer home and breeding ground is on islands off the Alaskan coast. When the breeding season has ended, groups of female seals, accompanied by the younger members of the herds, move southward on winter journeys along the west coast of North America. They may travel as much as 3,000 miles, reaching waters off California on their long winter tour.

The old, male fur seals do not take part in this migration. They remain in the Bay of Alaska and nearby waters, feeding on fish. In the spring, the old males return to the breeding grounds to await the coming of the females and their young companions.



10–6. Harems of fur seals in Alaska. (*U.S. Department of the Interior*)

10–7. Caribou are known to migrate between summer and winter feeding grounds. (*Hugh M. Halliday from Annan Photo Features*)

Some species of North American bats also migrate, moving southward in autumn and northward in spring. The habits of these small, flying mammals are not as well known as are the habits of various birds. It appears, however, that some bats travel long distances. They have even been known to alight on ships far out at sea.

The deerlike caribou of northern lands also migrate back and forth between summer and winter feeding grounds. Various other mammals engage in seasonal journeys, but in some cases their travels are not very extensive. House rats, for instance, may move out in the fields during the summer months, and return to the shelter of barns and warehouses when cold weather approaches.

Emigrations of squirrels. The grey squirrel is a species that has been known to emigrate upon a number of occasions. When this happens, large numbers of the animals travel away from the parent area, sometimes going

10–8. One of the most interesting emigrations is that of lemming populations. (*T. Anderson from Annan Photo Features*)

many miles. Such a mass emigration seems to take place when the squirrels have become overabundant. Scarcity of food may be a factor that impels them to depart. At any rate, there is no return journey, so it is a case of *emigration,* rather than migration.

Emigrations of lemmings. One of the strangest emigrations is performed by a little, mouselike animal known as the Norwegian lemming. This species normally lives on mountain plateaus in Norway. The lemmings find a home above the tree line, and feed upon grasses and lichens. In certain years, the lemmings begin to reproduce at an increased rate. Female lemmings bear young more often than is usual, and there are more young in each litter. Soon the lemming population has increased enormously, and vast numbers of the little animals are literally forced into the forests, which lie below the plateaus on the mountainsides.

Now a mass emigration begins, with the lemming horde moving ever downward toward the sea. As the horde travels on a journey that may last two or three years, it is pursued by hawks, owls, and mammals. Many lemmings are devoured, and many more perish in attempts to cross bodies of water that lie in their paths. But the survivors keep on going, and they finally reach the sea. Now they leap into the water, swim until exhaustion overtakes them, and perish by drowning.

This emigration of the lemmings may sound a little senseless to you. Certainly, all of the lemmings that emigrate are doomed sooner or later. But the mass emigration does serve to reduce overpopulation for a period of years. The lemmings that remain behind in their mountain homes now have enough food to survive.

Locust plagues. "Locust" is a name used in some parts of the world to describe certain types of grasshoppers that have been pests to mankind for

10–9. A farmer fighting a grasshopper plague in the late 1800's. (*USDA Photo*)

centuries. The locusts, like the Norwegian lemmings, sometimes become superabundant in their homelands. Then a "locust plague" occurs, and vast swarms of grasshoppers move across the land, destroying crops and all other plants they may encounter.

Such movements of grasshopper swarms, which may contain millions of the pests, are often called "migrations." But they actually are emigrations, because there is no return journey. Some swarms even fly out to sea for hundreds of miles on an obviously pointless mission. Plagues of grasshoppers have occurred in Asia, Africa, North America, and South America. Some of them have left widespread areas bare of all vegetation.

CHEMICAL CONDITIONS IN THE ENVIRONMENT

Chemical substances in the surroundings of living things have marked effects upon their welfare. This is true whether the organisms are in the air, on the ground, in the soil, or in the water. These chemical substances vary from place to place, and from time to time. One of these important substances is salt.

You know, for instance, that sea water is quite salty. So is the water in some lakes that have no outlets. There is even some salt in the water you get from wells and streams. Where rivers empty into the sea, there is a mixture of sea water and fresh water, and the amount of salt in this water may change considerably as the tides rise and fall.

SALT CONCENTRATIONS AND AQUATIC ORGANISMS Are aquatic organisms generally adapted to survive changes in the salt content of the water? Or do you think such adaptations are found only in a few aquatic organisms?

You can get some information by testing small, aquatic animals with salt solutions. First, prepare 1 percent, 2 percent, and 4 percent solutions of common salt in water. As subjects to be tested use protozoans, water fleas, brine shrimps, or small aquatic worms.

Put one or more specimens on a blank slide in a drop of water. Cover with a cover glass, and focus upon a specimen with the low power of a microscope. Now place a drop of 1 percent salt solution next to one edge of the cover glass. Place a piece of paper toweling along the opposite edge. The water under the cover glass will be soaked up by the toweling, and at the same time, the salt solution will be drawn under the cover glass.

Note any reactions of your specimen when it encounters the salt solution. Repeat the test with other specimens, using 2 percent and 4 percent salt solutions. Observe their reactions. Finally, use the same procedure to replace the salt solution under the cover glass with a drop of tap water. See how long it takes for an organism to recover from being in salt solution.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did any of the organisms tested seem to have adaptations for surviving in salt solution? Explain.
2. Did the organisms tested act the same way when exposed to different amounts of salt in the water? What evidences do you have?

Among animals, there are many adaptations that are related to social life. The members of various species live together in groups. Thus, we speak of *herds* of deer or fur seals, *colonies* of ants or bees, and *schools* of fish.

The termite colony. Termites are among the insects that develop a complex social life. They also have various adaptations of behavior that are rather unusual. Termites of many species are common in tropical areas, and some species are found as far north as Canada. These insects also are known as "white ants," probably because they live in colonies, and because some of them are antlike in form and a dirty white in color.

Termites are wood eaters. In nature they tunnel in the trunks and roots of trees to obtain food and build their colonial homes. A colony includes the following members: (a) a *queen*, (b) one or more fertile males or *kings*, (c) a large number of *workers*, and (d) two kinds of *soldiers*. Only the kings and queens of some species have wings, and the queens soon lose these structures.

10–10. Winged kings and queens of harvester termites. (*Jane Burton from Photo Researchers*)

10–11. Common eastern termites. (*Hugh Spencer*)

The workers are both male and female, but they do not reproduce. They build the colonial home by tunneling in wood, and feed and care for the queen and the young termites. Some termites even raise fungi in their colonies, as an added source of food. One type of termite soldier has powerful mouth parts, adapted for combat with other small animals. Another type of soldier depends upon a sticky fluid which it discharges from a pore in its head.

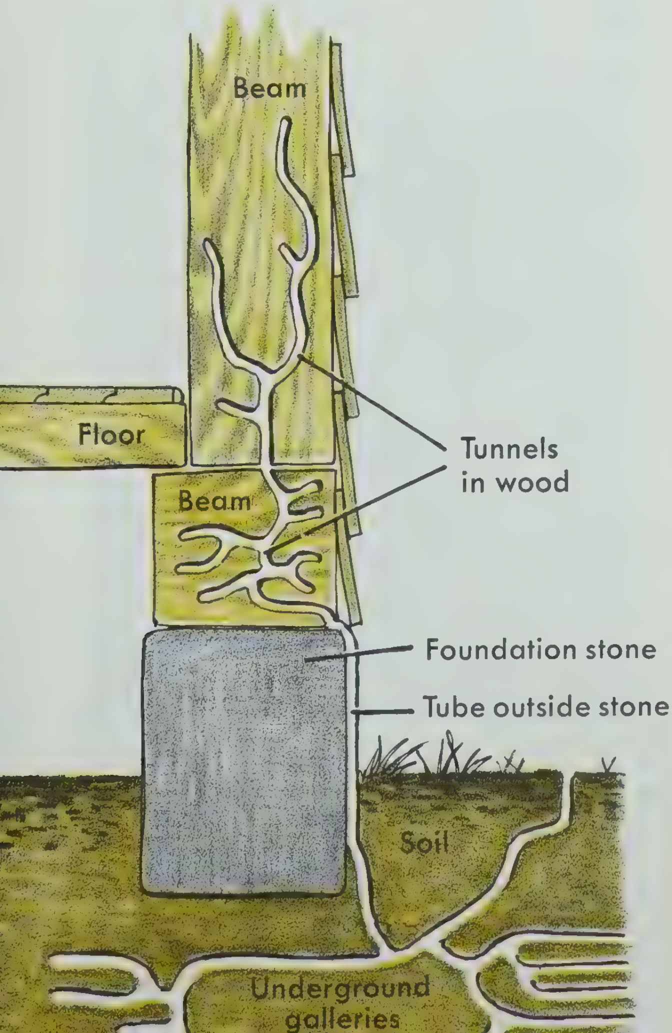
Termites have proved to be a nuisance from our point of view. Certain species establish their colonial homes in the beams that support the floors and walls of houses. Within the beams, they tunnel busily until little more than a wooden shell remains. They will also tunnel in books or other materials that are made from forest products.

Figure 10–12 shows a termite colony in a wooden beam near the floor of a house. Note the tube which connects the tunnels in the wood with tunnels in the soil. The termite workers mix mud and sawdust to make these tubes. They line their passageways with the same kind of "cement." They will not build colonies unless they find a spot where moist soil can be reached. Except for the winged members of the group, they live in darkness.

Now look at Fig. 10–12 again. Start with the tunnels in the soil. From one of these tunnels a tube runs over the surface of a foundation stone. The tube provides a sealed passageway to a wooden beam in which the termites are tunneling. Sooner or later the beam will be largely eaten up, although its outer surface may show no sign of the damage.

Another peculiar fact about termites is that they can get nourishment

10–12. A diagram of a typical termite colonial establishment.



10–13. A honeybee hive. (*Doering from Annan Photo Features*)

from wood. This is something that you could not do. Neither can a termite, unless it has help from another organism. But a termite has such help, as you will learn in the next section of this chapter.

The honeybee establishment. Honeybees provide another example of insects that live in colonies and develop special groups or *castes* of individuals. We raise honeybees in hives, but in nature, colonies are likely to be set up in hollow trees. A colony may contain up to 90,000 bees.

The largest caste in the honeybee group is made up of workers. These workers are females, but they are not able to mate or produce eggs. At the beginning of their rather short lives, they act as nurses, caring for the needs of the larvae from which more bees will develop. Later, the workers leave the hive to collect nectar and pollen, which are the staple foods. Workers also carry

10–14. Honeybees on the comb. (*Syd Greenberg from Photo Researchers*)

water to the hive, and fan the air of the hive with their wings, when the weather is warm.

The structure, which the worker bees produce in the hive, is a series of *combs* made of wax, and is divided into many small cells. In a central comb, the cells house eggs, larvae, and pupae. The other combs are filled with stored food in the form of honey. This is a reserve food supply, for use when nectar and pollen are not available.

The central figure in the bee colony is the queen. This queen is a large bee that has only one function—the production of eggs. The queen develops from a fertilized egg that normally would produce a worker bee. This egg, however, is hatched in a special cell, and the larva that comes from it is fed a special diet. The result is a fertile queen.

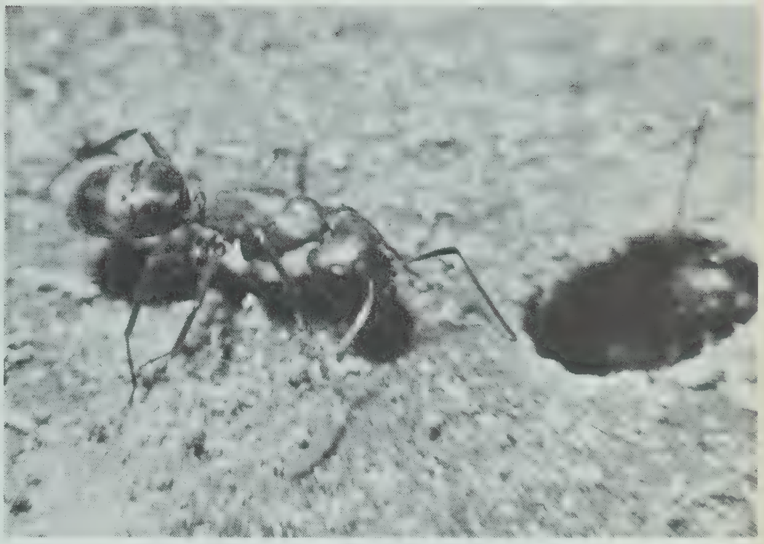
The male honeybees are called *drones*. There are always more of these drones than seems to be necessary. Only one of them is needed to fertilize the queen, who mates but once in her lifetime. When we say "busy as a bee" we are surely thinking of worker bees rather than drones. In the end, the drones pay dearly for their idleness. In late summer or autumn, when food gathering has slowed down, the worker bees drive the drones out of the hive to a death by starvation.

A bee colony tends to become overpopulated if it is successful. Then the workers prepare several cells for the production of new queens. After this has been done, the bees *swarm.* In swarming, the old queen and most of the workers leave the hive and seek a new abode. Some workers remain with the old colony, which keeps on developing as soon as a new queen becomes established.

Colonies of ants. Ants are very common in tropical areas, but they also are found in many other parts of the world. They even appear in barren desert areas. There are many different species of ants, and they vary a good deal in habits. Some of them set up their colo-

10–15. A queen bee. (*Lennart Nilsson from Black Star*)

10–16. Carpenter ants at home on an old dried log. (*Hugh Spencer*)



10–17. The South American soldier ant. (*Russ Kinne from Photo Researchers*)

nial homes in the ground. Other ants build mounds of earth, with galleries both in the mounds and the soil beneath. Various ant species tunnel in wood. In fact, some ants tunnel in wood about as much as termites do. But ants do not eat the wood. They are merely building a home.

Ant castes include queens, males, and workers. A colony may have one or several queens. These queens develop wings, but soon lose them. They carry out the normal queen function of producing eggs. Male ants also are winged, and they only appear during the reproductive season. The sole function of the males is to fertilize the queens.

As in the case of bees, the largest group of an ant colony is made up of workers. Ant workers, however, are often of several types which differ in structure, size, and function. Some of them generally act as food gatherers, some as soldiers that guard the colonial home, and others as nurses that care for eggs, larvae, and pupae.

The *soldier ants,* which live in the jungles of tropical America, have some striking social habits. These ants are about an inch in length, and they have formidable mouth parts. One ant, of course, would be no great threat to an animal like a rat, but several thousand ants attacking at once would quickly overcome the rat's defenses.

Soldier ants go on food-seeking marches through tropical forests. Thousands of them march in a long column. At night, they form a living ball of ants, and await the coming of the next dawn. They fall upon all sorts of luckless animals, and pick their flesh down to the bones. Some fairly large animals are included among their victims.

Soldier ants, however, have enemies with which they cannot cope. Some tropical birds are aggressive enough to capture and eat them. So does the giant South American anteater. This animal uses its long slender tongue to lick up ants marching along a jungle trail.

The *leaf-cutter ants* of the American tropics also have a unique mode of life. They are ants that feed largely on fungi. They farm or raise these fungi in their colonial dwellings. Worker ants bring pieces of leaves into an ant gallery, and prepare a bed of decaying

10–18. The giant South American anteater. (*Photo Researchers*)

material upon which the fungi will grow. If it is a new colony, the queen ant brings with her a portion of the desired fungus. This is duly planted, and a fungus farm is soon in operation.

When you study Chapter 20, you will read about some little sap-sucking bugs that are called ***aphids*** (*a*-fuds). These aphids secrete a sugary substance that is called *honeydew.* Many ants are very fond of anything that contains sugar. So it is not surprising that they carry aphids about, and put them on plants from which they can obtain sap. Then the ants visit their aphids regularly and feed upon the honeydew.

The *cornfield ant* is a species that carries this aphid-tending somewhat further. In autumn, the cornfield ant collects the eggs of one aphid species, and stores them over the winter in the ant colony. When young aphids hatch out in the spring, the cornfield ant transports them to the roots of various plants, including corn plants. Now the aphids can suck sap and produce honeydew. Sometimes these aphids are called "ant cows."

10–19. A leaf-cutter ant. (*R. Freund from Photo Researchers*)

10–20. Certain ants "milk" aphids for their honeydew. (*Lane from Annan Photo Features*)

A rather surprising fact about some ant species is that they practice slavery. The queen of such a species will invade the colonial home of another species and "take over." Her own offspring may soon dominate this colony. More workers, however, may be needed. If so, the slave-making ants raid other colonies, capture workers, and bring them back to act as slaves.

ADAPTATIONS AND BEHAVIOR

In addition to the insect societies discussed in the preceding pages, there are many examples of animals that lead more or less social lives. Various species of monkeys live in troupes or bands. Prairie dogs develop communities or "towns" in which the ground is pockmarked by their burrows. Wolves band together in the winter when food is scarce. When wolves hunt in packs, they are able to kill larger animals.

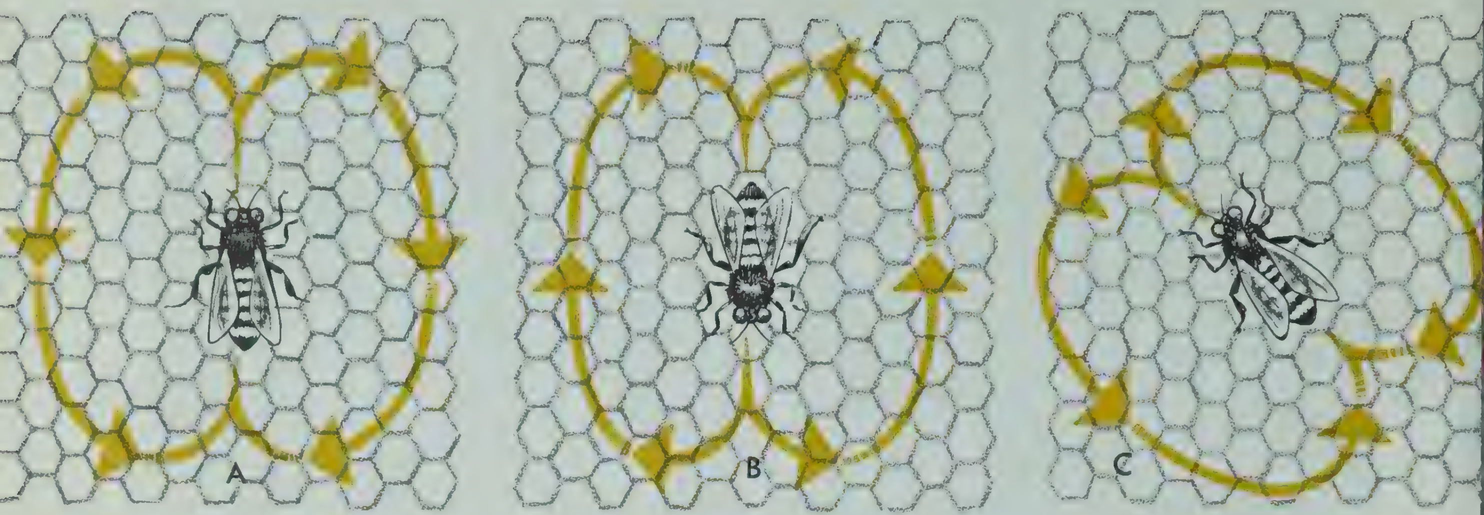
Communication. When animals live in social groups, it is a great advantage to be able to communicate. Thus, certain calls indicate distress, anger, danger, or the discovery of food. A flock of common crows, feeding in a field, will usually post a sentinel in a tall tree nearby. If a man approaches, the sentinel will sound the warning call, and the crows will depart without loss of time.

Many other birds and various mammals are able to communicate in much the same way. A ground squirrel, that detects the presence of an enemy, will utter a shrill whistle before it ducks into its burrow. Other ground squirrels nearby will quickly take cover. A lost, hungry kitten will utter cries of distress until its mother comes to the rescue.

Starlings are introduced birds that have become pests in some eastern cities. In certain cases, it has proved possible to drive them out of town. First, the cries of distress uttered by a frightened starling are recorded. Then the recording is broadcast in the area where the starlings roost at night. Upon hearing the distress call, many starlings have promptly left the area.

One of the more novel types of communication is the "dance of the bees." The Austrian biologist, Von Frisch, has recently discovered how and why honeybees engage in this dance. If a worker bee finds food within 100 yards of the hive, it returns to the hive and does a *round dance* on the vertical side of a bee comb. In this dance, the bee travels in a circle, making one round to the left, one round to the right, and so on. The other worker bees observe the dance, and apparently know what to look for, because of the odor of the nectar on the dancing bee. They fly out of the hive and seek the food source within 100 yards of home.

If the food source is a half mile away, however, the dance is very differ-



10–21. Bee dances indicate the distance and direction of a food source. (A) The food lies in a direct line toward the sun; (B) the food is in a line directly away from the sun; (C) the food is toward the sun, but to the left of the sun's position.

ent. Now the bee performs the *wagging dance.* This dance informs the other bees that the food source may be found about a half mile away in a particular direction. Figure 10–21 shows how this is done. In *A,* the dancing bee moves through a figure-8 on the comb surface. As the bee travels upward, between the two loops of the figure-8, she wags her abdomen back and forth. The fact that the bee is facing directly upward at this point means that the food is in a direct line toward the sun.

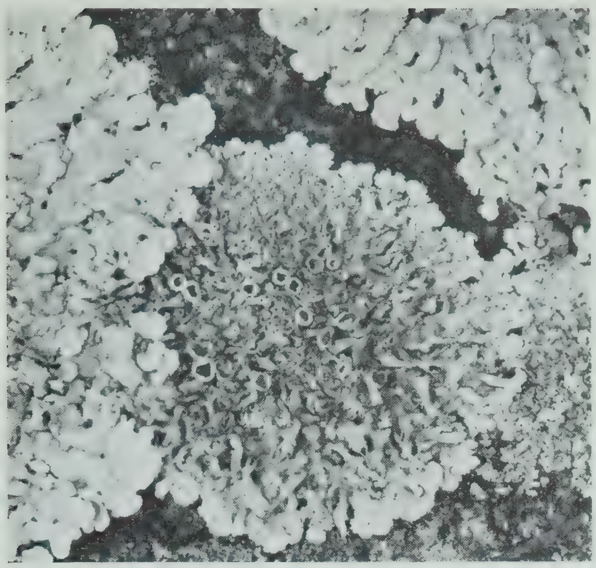
Now look at *B* in Fig. 10–21. Here the bee is headed downward, as she passes between the two loops of the figure-8. This means that the food is on a line directly *away* from the sun. In *C* the bee is reporting food located toward the sun, but somewhat to the left of the sun's position. Note that the bee's body points upward, but at an angle to the vertical.

How does the bee indicate the distance to the food source? This is also fairly simple. The more loops the bee travels, the closer the food. Thus, if the bee makes eight loops, the food is closer than would be the case if the bee made four loops.

Other bees look on and even join in the dance. Then they fly to the place where the food has been reported. This explains something that has puzzled us for many years. It was long ago observed that a few minutes after one or two honeybees find a new source of food, large numbers of bees appear at this spot. Now we know how one bee can inform other bees of a food find.

Cooperation among organisms. There are many examples of relationships between the members of *different* species. Some relationships are quite close, and in other cases the relationships operate only now and then. When two different organisms are associated in some way, and they both profit by the association, it is a case of ***mutualism*** (*mew*-tew-*uh*-lizm). For example, the ***lichen*** (*li*-ken) that is made up of an alga and a fungus (see page 233) provides an example of mutualism.

Another good example of mutualism has to do with termites. A termite harbors a certain type of protozoan in



10–22. The lichen provides an example of mutualism. (*Hugh Spencer*)

its intestine. This protozoan can digest wood fiber. In the termite's intestine the protozoan has a place to live, and plenty of wood fiber to digest. The termite also benefits, because it is able to get nourishment from wood fiber after the wood has been acted upon by the protozoan. In fact, the termite would starve if it did not have its protozoan ally.

Fortunately for termites, they generally have large numbers of the required protozoans in their intestines. This is assured soon after a termite egg hatches. Worker termites feed the young on partly digested food. Since this food comes from the bodies of adult termites, it is full of protozoans. In this manner, the protozoans are passed along from one generation of termites to another. You can readily see that both termites and protozoans benefit from the association.

Another example that may be a case of mutualism involves various trees, other higher plants with fleshy stems, and fungi. Pine trees and oak trees, for instance, often have fungi growing on their root systems. The fungi form a sort of sheath around a root. Parts of the fungi grow right into the root tissues. Such roots have few if any root hairs.

In this association it is believed that the fungus acts to absorb water and minerals from the soil. If this is the case, the tree benefits. The fungus is also believed to benefit by absorbing growth materials from the roots of the tree. This type of association is not a rare thing in nature, for it has been found to affect a number of higher plants.

Many associations between different organisms are more casual than the preceding examples indicate. A woodchuck, for instance, digs a burrow in a hillside. A number of insects take refuge in the burrow. The insects may profit, because they have a reasonably safe retreat. The woodchuck does not profit, but at the same time, it is not injured in any way. In a case like this we say that the two organisms are *commensals* (comm-*enn*-suls).

10–23. A hydroid colony on a hermit crab's shell provides an example of commensalism. (*Walter Dawn*)

10–24. A male bird will fight to defend his territory from other male birds. (*Eric Hosking from Photo Researchers*)

Competition. Of course, if the insects living in the woodchuck's burrow were blood suckers and attacked the woodchuck, the two species would not be commensals. In such a case, the insects would be called parasites, and the woodchuck would be their host. You could also say that the insects would be natural enemies of their host, the woodchuck.

This example illustrates the fact that while there are many cases of cooperation among organisms, there are also many cases of *competition.* The competition is part of the unending effort to find food and security, both of which are necessary for survival.

A male bird comes north in the spring and selects a territory, where its mate will nest and rear a brood of young. The territory is one which provides a suitable nesting place and the promise of a food supply. The male bird spends a lot of its time standing guard over this territory. It utters warning cries, and it attacks other birds that enter its domain. Various mammals also protect their home territories. Even a rabbit may attempt to defend its briar patch against another rabbit.

WORD MEANINGS

On a sheet of paper in your notebook copy the words in the first column. Write in the statement from the second column that goes best with each of these words.

1. hibernation	A food used by honeybees.
2. soldiers	One-way journey performed by an animal.
3. drones	Special frog structures that contain stored foods.
4. emigration	Castes of termites that defend the colony.
5. commensals	Home areas that various animals try to defend.
6. fat bodies	Condition in which life processes slow down.
7. territories	A secretion of aphids.
8. protozoans	Two-way journey performed by an animal.
9. migration	Organisms that live in the intestines of termites.
10. round dance	Male honeybees.

11. pollen
12. honeydew

Organisms that live together with no injury and perhaps some benefit to one of them.

A way in which bees indicate the location of food.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. A leopard frog can obtain energy from special fat bodies while it hibernates.
2. When a leopard frog hibernates at the bottom of a pond, it obtains oxygen by means of gills.
3. When a ground squirrel hibernates, its breathing rate falls, but its heart rate and body temperature remain unchanged.
4. Although raccoons and skunks remain in dens during the very cold weather, they do not hibernate.
5. Birds that move back and forth between a summer and winter home are said to emigrate.
6. When fur seals migrate, all the members of the herd take part in the long journey.
7. Lemming emigration is usually a response to a greatly reduced population size.
8. The main function of a queen termite is to feed the young.
9. Termites will only build a colonial home in a spot where the surrounding soil is dry.
10. Honeybee castes include queens, workers, and soldiers.
11. Honeybees store honey in structures known as combs.
12. In the honeybee society, drones do most of the food gathering.
13. Soldier ants attack and kill some of the larger animals.
14. Honeydew is a sugary substance secreted by aphids.
15. Ants are useful because they devour large numbers of aphids.
16. The round dance of the honeybee warns the other bees in the hive of approaching danger.
17. When two organisms are closely associated and both of them profit, it is a case of mutualism.
18. If you find a fungus growing on the roots of a tree, it is a sure sign that the fungus is a parasite.
19. When two animals are closely associated, and one of them suffers an injury from the other, they are commensals.
20. Competition is a relatively rare thing in nature.

DISCUSSION QUESTIONS

1. Of what advantage is hibernation to a species?
2. What happens to an animal's life processes during the period of hibernation?
3. What is the difference between migration and emigration?
4. What are some theories as to why birds migrate?
5. How do birds find their way when they migrate?
6. In what ways does emigration seem to be related to population increase?
7. What castes make up a termite colony? What is the function of each caste?
8. What kinds of insects raise fungi as a source of food?
9. In what sort of location would you expect to find a termite colony?
10. What castes make up a honeybee colony? What is the function of each caste?
11. How do ant castes (a) resemble, and (b) differ from termite castes and honeybee castes?
12. What is unusual about the behavior of the soldier ants? The leaf-cutter ants?
13. In what ways are certain ants associated with aphids?
14. How do some ants make "slaves" of other ants?
15. How does the wagging dance of a honeybee indicate the direction and distance of a food source? How does it differ from the round dance?
16. Why is it necessary for termites to have certain protozoans in their intestines?
17. In what way are fungi associated with the roots of various higher plants?
18. In what ways do animals tend to protect their territories?

THINGS TO DO

1. Visit an aquarium, botanical garden, museum, or zoo to observe examples of special adaptations. Group exhibits are expecially good because they indicate how various plants and animals are interrelated.
2. Prepare maps, and trace the migration routes of various animals such as the arctic tern, golden plover, and fur seal. Use different colors to indicate the routes of different animals. You may want to include routes of some species not mentioned in this book. Use reference books to gather information.
3. Obtain and display a sample of wood that has been attacked by

termites. Use a rip saw to make sections through the wood, and see how the interior is honeycombed by the termite galleries. Examine samples of the cement that termites use to line their galleries.

4. Set up an ant colony in a gallon battery jar. Cover the lower half of the jar with black paper to exclude light. Fill the jar half full of earth that is packed down lightly. Get this earth from an ant colony out of doors, and make sure that it includes a fairly large number of ants. It is best to dig in an ant hill or burrow. Put some food, such as a slice of bread or some food scraps on top of the soil in the jar. Cover the jar with a well-fitted screen so that the ants cannot escape. After two weeks, remove the black paper from the bottom of the jar. Now you can observe a good many ant galleries through the glass.
5. Make a strong sugar solution in water and place it in a flat dish out of doors. Observe what small animals are attracted to this food source. Among them will be a number of flying insects, as well as any ants that are in the vicinity. Several different species of ants, which vary in size and color, are likely to appear.
6. Put a bone with meat scraps attached to it on an ant hill. Over a period of several days, observe how the worker ants remove all of the fleshy material from the bone. This is one way you can get an animal's skeleton cleaned.
7. After consulting the references listed below and any others that may be available, prepare a report on how honeybees build combs in their hives, and how honey is produced from nectar.

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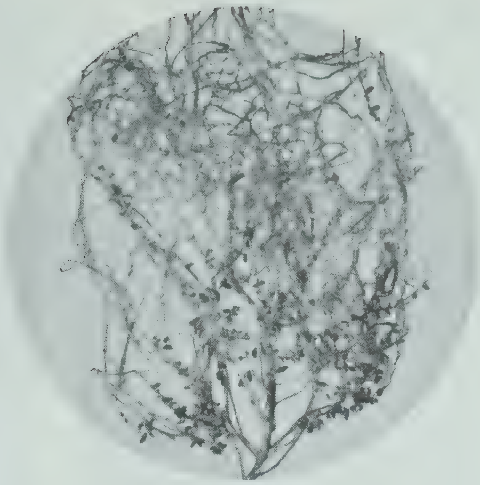


CHAPTER 11

Change and Decay

From your study of paramecium, you may remember that this little animal does not grow old and die in the usual sense. Instead, it grows to full size, and then divides to form two new cells. These new cells begin the process of life and growth all over again. Much the same sort of thing happens in the case of some other protists, such as bacteria. Of course, any individual may die due to very unfavorable conditions in its surroundings. Or it may be eaten by some other organism. But if life runs a normal course, the stages an organism passes through in each generation make up its ***life cycle.***

The life cycles of the more complex plants and animals are somewhat different. Following sprouting, hatching, or birth, comes a period of *youth,* in which growth takes place. Then there is a period of *maturity,* during which most organisms reproduce. Finally, there is a period of *old age,* which ends with the death of the individual. But since reproduction has usually taken place, the species continues to exist.

Life cycles of many organisms run their courses in a single season. But in some cases they extend over a period of years. Some of them are marked by special stages, as you shall see.

LIFE CYCLES OF ANIMALS

We can get some ideas about life cycles by studying insects. Insect life cycles are of two general types. The type shown in Fig. 11–2 is found among insects like the grasshoppers. In the autumn, adult female grasshoppers deposit their eggs in the soil at a depth of an inch or two. Here the eggs lie until the winter has passed.

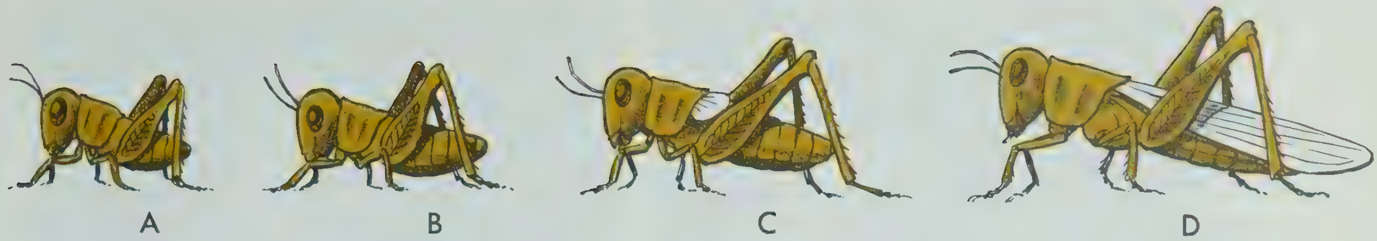
The grasshopper life cycle. A very young grasshopper has the general form and appearance of an adult. However, it does not have any wings and its sex organs are not developed. It is called a ***nymph*** (*nimf*). This nymph has chewing mouth parts, and promptly begins to feed upon the leaves and stems of various plants.

11–1. What stages in a human life cycle do these pictures represent? (*Standard Oil Co. N.J.; bottom left, Sybil Shelton from Monkmeyer*)

The nymph has an external covering or skeleton composed of a horny material called ***chitin*** (*ki*-tin). This external skeleton is like a coat of armor. It limits the extent to which the nymph can grow. But before long, the first-stage nymph sheds its external skeleton. Before a new skeleton forms and hardens, the insect increases in size. Now it has entered a second stage.

This process of eating, shedding the external skeleton, and growing is repeated as the nymph goes through several stages. In the later stages, the wings and sex organs begin to develop. They are fully formed when the adult stage is reached. Like the nymph, the adult grasshopper has chewing mouth parts, and continues to feed upon leaves and stems.

A moth life cycle. Other types of life cycles are also represented among the insects. A moth, for example, passes through a very different series of life



11–2. Life cycle of a grasshopper: (A) The first-stage nymph; (B) the second stage nymph; (C) the nymph with wings appearing; (D) the adult with full wing growth.

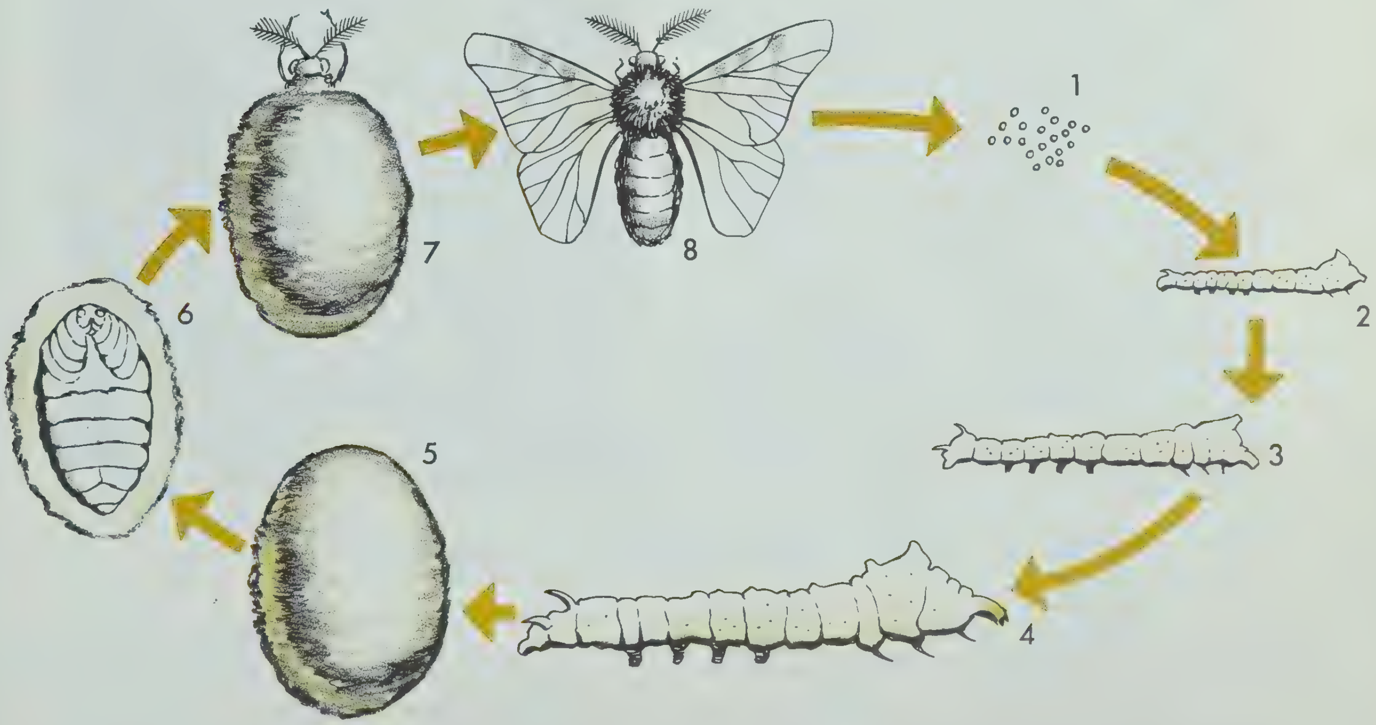
stages. (See Fig. 11–3.) Refer to this figure as you read about the cycle.

When a moth egg hatches, a ***larva*** (*lar*-vuh) is produced. This larva is wormlike, and not at all like the adult. It has chewing mouth parts, and proceeds to feed upon plant materials. In many species of moths, this is the only stage in which the insect takes food.

As the larva feeds, it grows, and stores up food reserves. Now it is ready for the next stage. First, the larva spins a cocoon. Within the cocoon the insect becomes a ***pupa*** (*pew*-puh). During this stage the insect cannot move about. But it is alive and active, and many changes in its structure and appearance are taking place.

Then the moth emerges from its cocoon as an adult. Now it has wings and mature sex organs. Adult life often is quite short, and during this period the main activity is mating and the production of eggs.

Other animal life cycles. Life cycles among animals vary a good deal. For instance, some insects bear their young



11–3. The life cycle of a moth is illustrated above. Stage 1, the eggs; stages 2–4, the larvae; stages 5–7, the pupae; stage 8, the adult.

11–4. The life cycle of the cecropia moth. Name the stages shown in the above pictures. (*Hugh Spencer*)

instead of laying eggs. Some species of fish and snakes also bear their young, while other fish and snakes lay eggs. But generally, there are periods of youth, maturity, and old age in animal life cycles. Some of these life cycles last only a few days, others for months, and some for many years.

AN ADULT INSECT

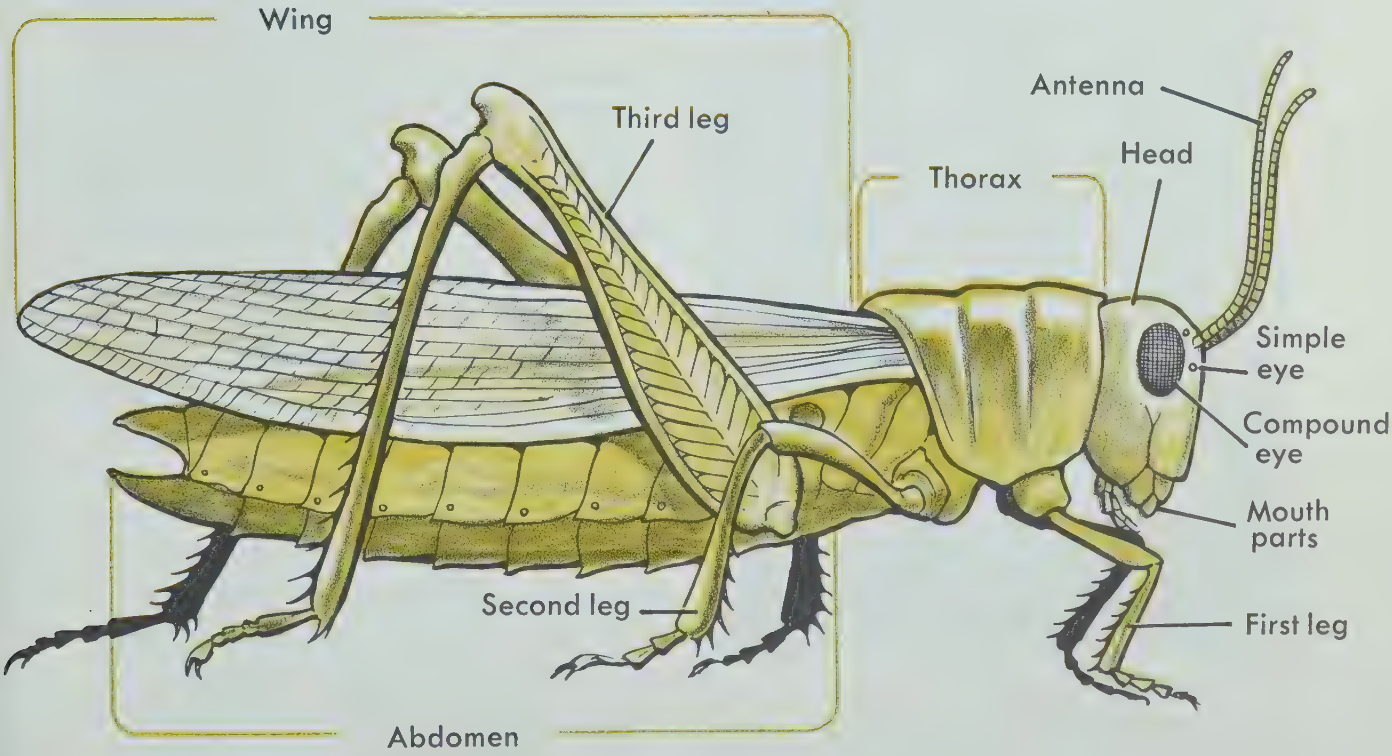
Knowing something about an adult insect's structures helps you to understand its life cycle. Wash off an insect that has been preserved in alcohol or formalin solution, and examine its parts with a hand lens. A grasshopper is a good type to study, because its parts are large enough to be seen readily. Check what you observe with the diagram shown in Fig. 11–5.

Note that the body consists of segments, some of them more or less joined together. Note also, that there are three pairs of legs. The body is covered with an external skeleton of chitin. There is no internal skeleton like the one in the body of a mammal. On the head are two large *compound* eyes, and two or three small *simple* eyes. A pair of segmented ***antennae*** (an-*tenn*-ee) extend forward from the head. The head also bears the mouth parts, which feature a pair of heavy *jaws,* used to shred plant materials.

Behind the head lies the ***thorax*** (*thor*-acks), which is made up of three segments partly joined together. The legs and the two pairs of wings are on the thorax. Behind the thorax lies the ***abdomen*** (*ab*-doh-m'n), which has a number of segments. Along the lower sides of some of these segments are tiny openings. These openings connect with air tubes that branch within the body.

ANALYSIS Prepare answers to the following questions in your notebook:

1. To do its work, one end of a muscle often is attached to something solid, such as a part of a skeleton. What do you think provides for such attachments in a grasshopper's body?
2. How do you think the cells within



11–5. External structures of the grasshopper.

a grasshopper's body obtain the oxygen they must have?

3. How do you think the wings are moved? What evidences do you have?

LIFE CYCLES OF PLANTS

Some of the plants are much longer lived than any of the animals. Various trees are known to have lived for many centuries. For example, some Douglas fir trees of the Pacific Northwest have lived for more than 2000 years.

Annuals, biennials, and perennials. Plants that live a number of years are what we call ***perennial*** (per-*enn*-ee-ul) plants. Many trees, bushes, grasses, and the familiar rhubarb and asparagus plants are of this type.

11–6. Some Douglas fir trees of the Pacific-Northwest have lived for more than 2,000 years. (*Weyerhaeuser Company*)

On the other hand, a large number of our land plants live out their life cycles in a single growing season. A radish plant, for example, sprouts in the spring, grows, produces its flowers and seeds, and dies when autumn frosts appear. Such a plant is called an ***annual*** (*an*-you-ul). There also are some plants that require two growing seasons to complete their life cycles. Beets, turnips, and carrots are well-known examples. In its first season, the plant develops leaves and a root system, but does not flower. During the second season, a tall stalk arises from the roots, and on it leaves, flowers, and seeds are produced. Such a plant is called a ***biennial*** (by-*enn*-ih-ul).

Plants and the soil. Our earth is very old, and land plants have lived upon it for millions of years. You have learned that such plants take water and minerals from the soil, and use these substances to make foods and grow. The soil water, of course, is replaced when it rains, or when snows melt. But what about the minerals that are necessary for plant growth? Is there any manner in which they too are restored to the soil?

Natural processes do tend to restore these minerals to the soil. Some of them come from rocks that are constantly breaking down. Some come from the decay of dead plants and animals. Under natural conditions, green plants grow and use the soil minerals to build plant protoplasm. If animals eat the plants, the minerals become part of animal protoplasm. Sooner or later, both the plants and the animals die. Then their bodies decay, and now at least some of the mineral elements are returned to the soil.

But when crop plants are grown, the result may be different. Some of our

11–7. A corn field that has been mined to exhaustion by "one-crop" planting. (*USDA Photo*)

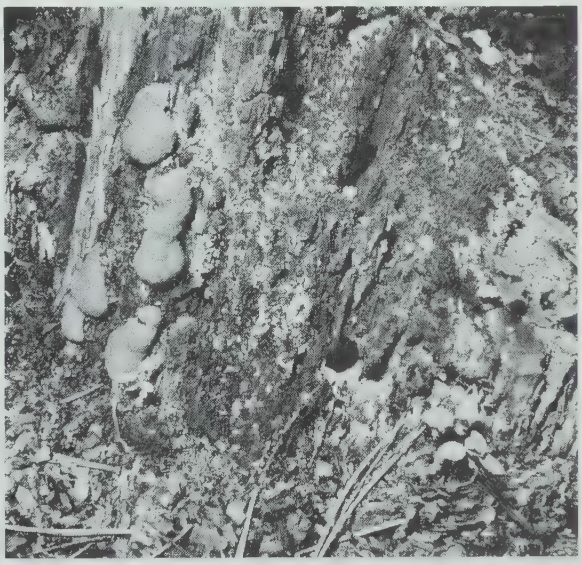
crop plants, such as corn, require a lot of mineral compounds for growth. If such compounds are not returned to the soil in some manner, and corn is raised in the same place for two or more seasons, production begins to fail. The soil has lost so much of its mineral content that it is no longer fertile. Plants may survive on this soil, but they do not flourish. In a case like this, people often say that the soil has been *mined* until it is exhausted.

The modern farmer avoids the disaster of mined and exhausted soil. If corn is grown in one season, some other crop, that adds needed mineral compounds to the soil, is grown during the next two or three seasons. Or, the farmer simply adds the required mineral compounds to the soil each year, so that good corn crops can be produced.

A DECAYING LOG

If you have a chance to examine a decaying log in a nearby forest, or even a piece of decaying wood in a vacant lot, you can observe how dead plant material is returned to the soil. It is best to study an old log that is well on its way to final breakup. It may already be partly buried in the topsoil.

Look for fungi growing on the surface of the log. They grow from parts that are down in the rotting wood. They get their food supplies from the dead tissues. Use a digging tool or hatchet to break away a part of the log. In its substance, you may find many branching, gray or white strands that also represent fungi. Because they are too small, you do not see the millions of tiny fungi and bacteria of decay that are feeding on the dead tissues of the log.



11–8. Slime mold, mosses, lichens, and liverworts on a decaying tree stump. (*Walter Dawn*)

Break up pieces of the rotting wood. See if you can find insects and other small invertebrates in the debris. Some of them, of course, are only present because the log provides a place of refuge.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What organisms do you think are most important in producing decay?
2. Of the organisms you found, which ones might be called saprophytes?
3. Given enough time, what will happen to the materials in the decaying log?

DECAY PROCESSES

For millions of years, plants and animals have lived out their life cycles and died. Have you ever stopped to think what our world would be like if natural processes of decay did not exist? Unless men did something about it, the land surface would certainly be cluttered with dead plants and animals. The seas would be filled with dead algae and other remains. Fortunately, however, natural decay processes do exist. The compounds and elements in the bodies of dead organisms are duly returned to the soil, air, and waters. But of course, this does not happen overnight.

The nature of decay. The decaying log on the forest floor tells part of the story. Tiny bacteria and fungi are the main agents that bring about its disintegration. But some other organisms also take part in the process. Ants and termites, for instance, may tunnel in the wood tissues, hastening the day when all of the wood substance will be broken down. Rainwater washes decay products down into the soil. Carefully study the picture on the cover of your text book. What natural decay processes are going on?

In a similar manner, a dead rabbit is soon attacked by a variety of saprophytes. Its tissues are broken down, and the decay products are added to soil, water, and air. The remains of plants and animals, together with organic wastes, become the substance called *humus*. Humus is commonly used to make soils more fertile.

Decay products and the topsoil. In Chapter 8, you learned that topsoil is a mixture of rock particles and decay products. Some of the decay products are broken down into molecules that dissolve in water. Other fibrous materials are not broken down so completely, but may serve a useful purpose, because they make fine-grained soils more porous.

It is important that topsoil should not be worn away by erosion, or made infertile by mining it to produce crops. In some parts of our country, thick lay-

11–9. A sample of topsoil. (*Grant Heilman*)

ers of topsoil have been formed. In other places topsoil layers are more shallow. In certain areas, this topsoil has been largely eroded away or mined to exhaustion.

Strangely enough, there are some localities in the world where the most fertile soil is not at or close to the surface. These are places where the soil is porous and rainfall is very heavy. Water soaking down through the soil carries decay products with it. Thus, the decay products that make the soil fertile are sometimes a number of feet below the surface.

11–10. Nitrogen-fixing bacteria nodules on the roots of a plant. (*Hugh Spencer*)

THE NITROGEN CYCLE

In making carbohydrates and fats, plants need three elements: carbon, hydrogen, and oxygen. They get these elements from carbon dioxide and water. But to make proteins, the plants must have not only carbon, hydrogen, and oxygen, but some other elements as well. They get these elements from mineral substances in the soil. Chief among them is *nitrogen,* which is an essential part of all protein molecules.

Nitrogen in air, soil, and water. Nitrogen makes up about 79 percent of the air. The air dissolves in water, and it penetrates the soil. So there is free nitrogen all around plants, whether they live on land or in the water. But this free nitrogen cannot be absorbed and used by most green plants.

However, green plants can and do use certain compounds that contain nitrogen. These compounds are called ***nitrates*** (*ny*-trayts). So having enough nitrates in water and soils is very necessary to the welfare of green plants.

The origins of nitrates. When lightning flashes across the sky, some nitrates are formed from gases of the air, and they fall with the rains. But another source of nitrates probably is much more important. This consists of nitrates that are produced by *nitrogen-fixing bacteria* of the soil, and certain algae that live in the water. These bacteria and algae have the ability to combine free nitrogen with other elements, and to produce nitrates. Thus, nitrates are made available both to land and aquatic plants.

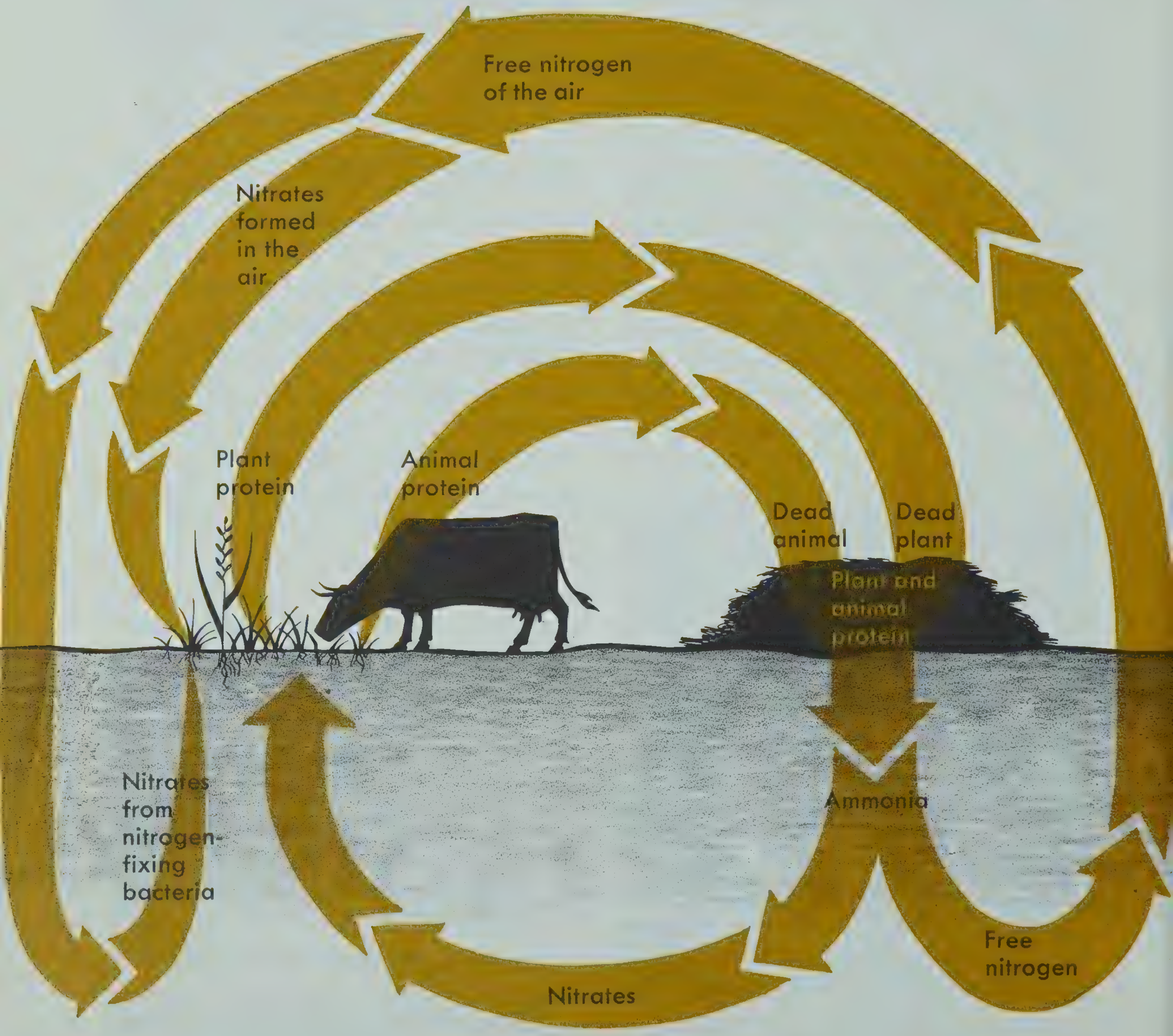
The nitrogen-fixing bacteria are of particular interest and importance. They often form colonies on the roots of plants belonging to the bean family, such as peas, beans, and clover. A fleshy nodule on the root marks the presence of such a colony. Farmers often raise clover in a crop-rotation program, so that nitrogen-fixing bacteria on the clover roots will add nitrates to the soil. This makes the soil more fertile, and paves the way for raising other crops.

How nitrates are used. A crop plant, such as corn, absorbs nitrates from the

soil along with soil water. Then the nitrates are used in the manufacture of plant proteins. The corn plant grows, prospers, and produces ears bearing seeds or grains. A mouse comes into the corn patch and eats some of the corn grains. Now the plant proteins are broken down by digestion in the mouse, and some of the elements in them are reassembled to form mouse proteins.

So the nitrogen in the nitrates has passed from the soil to the corn plant, and then on to the mouse. In time, the mouse may be captured and eaten by a cat. Again, the mouse proteins are digested in the cat's body, and some of the molecules in them are used to form cat proteins. This is another way of saying that proteins, like other food materials, are passed along in food chains.

Sooner or later, the corn plant, which also has proteins in its leaves, stems, and roots, comes to the end of its life cycle. So do the animals that have used the proteins in the corn grains.



11–11. Trace the pattern of the nitrogen cycle pictured above.

When such plants and animals die, decay begins.

Protein decay. As an example, let us suppose that the mouse which ate the corn grains dies of old age. Bacteria of decay soon are at work feeding upon the mouse tissues. Mouse proteins are broken down by these bacteria and form ammonia. Ammonia is made up of nitrogen and hydrogen.

Now two other groups of bacteria take over. One group uses ammonia to make nitrates again. This provides another source of nitrates for use by green plants. The other group of bacteria breaks down ammonia, and as a result, free nitrogen is returned to the air. This free nitrogen, of course, is no longer available for use by green plants.

A never-ending cycle. We have been discussing what happens to proteins in the growth and decay of plants and animals. The story is summarized in Fig. 11–11. When you examine this figure, remember that proteins always contain the element nitrogen.

In Fig. 11–11, you can see that land plants get nitrates from three sources: (a) nitrates formed by nitrogen-fixing bacteria, (b) nitrates that result from decay, and (c) nitrates produced in the air during electrical discharges. It also shows that when proteins decay, the product is ammonia. Then ammonia is used to build nitrates by one group of soil bacteria, or is broken down by another group of soil bacteria.

So an endless ***nitrogen cycle*** goes on in nature. Consider, for instance, a single nitrogen molecule. Let us say that it is a free molecule of N_2 in air that has penetrated the soil. Nitrogen-fixing bacteria use the molecule to make a nitrate. The nitrate is then used by a green plant, and the N_2 becomes part of a plant protein. But the plant is eaten by an animal, and before long the N_2 is part of an animal protein. In the end, the animal dies and decays. Now the N_2 molecule is part of the decay product, ammonia. Finally, soil bacteria break down the ammonia, and the N_2 is once more back in the air.

You should note that several groups of bacteria are involved in the nitrogen cycle. We often think of bacteria as being the cause of various diseases, and indeed, some of them are. But the bacteria that play roles in the nitrogen cycle are of great value. They make it possible for green plants to grow, and thus to feed the world.

WORD MEANINGS

On a sheet of paper in your notebook, copy the list of words in the first column. Write in the statement from the second column that goes best with each of these words.

1. chitin	A fleshy swelling that contains bacteria, and is found on a root.
2. decay	
3. erosion	Part of an insect's body to which the legs are attached.

4. maturity
5. nitrogen
6. nitrogen-fixing bacteria
7. nodule
8. nymph
9. saprophyte
10. thorax

The breakdown of dead plants and animals.
Any plant that obtains energy from the bodies of dead organisms.
Process by which soil is worn away.
Substance that makes up 79 percent of the air.
Organisms that can make nitrates from elements in air.
Material that makes up the external skeleton of an insect.
Reproductive period of life.
A stage in the life cycle of a grasshopper that does not occur in the life cycle of a moth.

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. A life cycle is best defined as (a) a cell dividing to become two cells; (b) the time when an organism dies; (c) the period of life called "old age"; (d) the stages an organism passes through in each generation.
2. A moth larva is (a) a wormlike organism; (b) the egg-laying stage; (c) found within a cocoon; (d) developed from the pupa.
3. Humus (a) is small rock particles; (b) is the remains of plant and animals in soil; (c) decreases the water-holding ability of soil; (d) is seldom found in topsoil.
4. A carbohydrate (a) is an element; (b) contains carbon, hydrogen, and oxygen; (c) is a good nitrogen source; (d) has the general formula CO_2.
5. Nitrates (a) are a special kind of bacteria; (b) are added to the soil by "mining"; (c) contain nitrogen in a form available to plants; (d) result when bacteria release free nitrogen into the air.
6. Which of the following kinds of organisms are affected by the nitrogen cycle? (a) higher plants; (b) animals; (c) bacteria; (d) all of these.
7. A biennial is a plant (a) that lives many years; (b) like a radish, that lives only one season; (c) that produces its seeds during the second growing season and then dies; (d) that lives on the bodies of dead organisms.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Some organisms do not grow old and die in the usual sense.
2. The period of a life cycle in which growth takes place is called maturity.
3. Female grasshoppers usually lay their eggs on the leaves of trees.
4. A grasshopper nymph must shed its skeleton in order to grow.
5. The stages in the life cycle of a moth are: egg, nymph, pupa, adult.
6. Some adult moths do not eat.
7. Insects have a skeleton much like the one found in your body.
8. Insect wings generally are attached to the abdomen.
9. Most trees are annuals.
10. Soil water comes from rain and snow.
11. Corn grows best in "mined" soil.
12. Crop rotation is a means used to restore soil minerals.
13. Decay can take place only when living things are present.
14. The world would be a better place for organisms to live if decay did not take place.
15. Nitrogen is an element present in protein molecules and absent in carbohydrate molecules.
16. Most of our air is composed of the element oxygen.
17. Nitrates are compounds useful to green plants.
18. Nitrogen-fixing bacteria change nitrates into free nitrogen gas.
19. Plants belonging to the bean family are of special use in crop rotation programs.
20. Lightning flashes may serve to make soil more fertile.
21. Ammonia may be produced when proteins decay.
22. Soil bacteria should be thought of as generally harmful to life.
23. The nitrogen cycle is an example of a way in which living and nonliving things affect each other.

DISCUSSION QUESTIONS

1. Explain what is meant by the statement, "Some organisms do not die."
2. In what ways are the stages in the life cycle of a grasshopper similar to those in a moth's life cycle? How are they different?
3. Describe the life cycle of a human.
4. What advantages does an external skeleton give to an insect?
5. Distinguish between the thorax and the abdomen of an insect's body.
6. What would you have to know in order to decide if a certain plant was an annual, a biennial, or a perennial? Explain.
7. List the ways minerals are removed from topsoil.
8. Once soil has been "mined," how can minerals be restored?
9. Explain how animals obtain the minerals needed in their bodies.

10. What is decay?
11. In what ways is decay a desirable process? A harmful process?
12. Describe the way topsoil is formed.
13. How is it possible for the most fertile soil in an area to be several feet below the surface?
14. Why are nitrates such important soil minerals?
15. What is meant by the "nitrogen cycle"?
16. What role do bacteria play in the nitrogen cycle?
17. Why are members of the bean family of particular importance in crop rotation programs?
18. In what ways are animals dependent upon plants for proteins? For carbohydrates?

THINGS TO DO

1. Observe the action of soil decay organisms by doing the following: Place pieces of such things as leaves, twigs, dead insects, paper, and cloth on the surface of some soil in a flower pot. Moisten the objects and the soil with water. Cover the pot with a thin piece of plastic held down by a rubber band around the pot. Keep the soil moist by setting it in a pan containing a few inches of water. Check the objects every few days, and look for signs of decay. Try to decide which items decay most rapidly, and which decay more slowly.
2. Dig up a clover plant or some other member of the bean family. Be sure to get out as much of the root system as possible. Wash the soil from the roots and see if you can find any nodules on them. Nodules look like small swellings. The nodules may be very numerous or there may be only a few nodules, or none at all. If you find a nodule, cut it open and look inside. You may wish to smash a small nodule between two microscope slides. Stir a bit of the smashed material into a drop of water on a third slide, and study it with high power of a microscope. Nitrogen-fixing bacteria that occur in nodules can be stained by using methylene blue.
3. Prepare a bulletin board display to illustrate the nitrogen cycle. Use sketches or pictures to represent the organisms in the cycle, and arrows to indicate how the nitrogen passes from one part of the cycle to another.
4. Using actual specimens or pictures, prepare a display to illustrate the life cycles of a plant and an animal.
5. Make a study of soil conditions in your part of the country. Find out what soil problems face plant growers, and how these problems are being solved. Report your findings to the class.

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BLOCK II

Laboratory Investigations

This portion of your biology book is divided into three parts, as follows:

Part I deals with aquariums and terrariums; how to set them up and how to maintain them.

Part II is made up of various demonstrations and investigations that deal with topics discussed in Block II.

Part III describes a method you can use in the field study of a land community.

PART I: AQUARIUMS AND TERRARIUMS AS SAMPLE COMMUNITIES

Aquariums and terrariums are not only interesting, but also very useful. They provide opportunities to observe the habits of many plants and animals. They are places where you can keep various plants and animals that you bring in. Although they are man-made, they are small samples of communities, and by studying them you can learn many things about community life. Finally, certain plants and animals from aquariums or terrariums will prove useful in carrying out some of your experiments.

Depending upon where you live, it often is possible to obtain many of the things you need for an aquarium or terrarium in a nearby stream, pond, and forest. Other items may be purchased from pet shops, department stores, and biological supply houses.

SETTING UP A FRESHWATER AQUARIUM Most school aquariums are set up in a container like that shown in Fig. L–1. Usually, the container holds from three to five gallons of water. But there are larger containers, and smaller ones too. You can even set up an aquarium in a gallon battery jar.

Wash a quantity of both sand and gravel until they are quite clean. Put about two inches of gravel on the bottom of the aquarium, and cover it with an inch or two of sand. Place several small stones on top of the sand. These

L–1. A general purpose school aquarium.

stones will shelter small, sensitive organisms from the direct rays of sunlight.

Root a number of aquatic plants in the sand, as shown in Fig. L–1. One type you can use is the *Elodea* you read about on page 26. *Elodea* will live either rooted, or just floating in the water. Another good type, that can be either rooted or floating, is *Cabomba*. A rooted type that has bladelike leaves is *Sagittaria*. You can add some duckweed, which is a small, floating plant that provides food for fish.

Now put your aquarium where it will receive partial sunlight. Fill it with clear pond water. Cover it with a glass plate or heavy plastic sheet to prevent rapid loss of water. Wait a day or two until the water becomes settled, then place the animals in the aquarium.

The average person tends to put too much animal life in the aquarium. In a medium-sized container you can, of course, have a half dozen small pond snails, a small pond clam, and perhaps a small crayfish. But fish are another matter. For each two square feet of water surface you can have a fish one inch long.

You can have a small tadpole in the aquarium rather than a fish. You can also keep a few more fish or tadpoles, provided you supply extra food and oxygen. Food is no problem, because you can get fish food at any pet shop. But do not overfeed, or the extra food will decay and foul the water. Added oxygen can be provided by a small aquarium pump. This is a little air pump driven by a tiny electric motor. It pumps air through a tube into the water.

After a time, you may find that heavy growths of algae are forming on the inner surfaces of the aquarium glass. This may mean that your aquarium is in a place where it gets too much light. Clean off the glass, and move the aquarium to a less well-lighted spot.

ANALYSIS After you have set up or studied an aquarium, prepare answers to the following questions in your notebook:

1. Is it possible that there are bac-

teria, protozoa, or other small forms of life in the aquarium? How could you find out? If so, where have they come from?

2. Why does good light favor the rapid growth and increase of algae?
3. Sometimes fish in an aquarium keep coming to the surface to gulp air. What does this suggest? What may be done about it?

OTHER TYPES OF AQUARIUMS It also is possible to have a saltwater aquarium, if sea water and marine plants and animals are available. You prepare the aquarium in the manner already described, except that the water and the organisms come from the sea.

You may be able to develop a *balanced aquarium* of either the fresh-water or saltwater type. You may not succeed every time you try this, but it is possible. The idea is to have an aquarium in which there is such a balance that everything keeps on living, even though the aquarium is sealed up. This means that the animals must get their food directly or indirectly from the aquarium plants. The aquarium plants must get carbon dioxide and nitrates from the water. Both plants and animals must have oxygen supplies. If you try this, be sure to avoid the temptation of putting too much animal life in the aquarium.

A BOG TERRARIUM To set up a bog terrarium, you can use a regular aquarium container and its glass cover, as shown in Fig. L–2. A standard terrarium container, however, provides more space for ferns and other taller plants to grow.

A bog terrarium is a suitable place for plants that grow in very moist situations and on acid soils. In it, you also can house certain small animals that are favored by moist environments.

Begin by putting about an inch of sand on the bottom of your container.

L–2. A general purpose school terrarium.

Cover this with a layer of bog soil, which slopes from a thickness of about four inches at one end of the container to an inch at the other (shallow) end. You can sink a culture bowl in the soil at the shallow end to form a miniature pond.

At the shallow end, which is going to be the wet end, plant such things as liverworts and mosses that grow in very wet places. Just beyond them is a good place for pitcher plants or other carnivorous plants, like the sundews. On the higher ground put ferns, fungi, and club mosses. Any spaces between these plants can be filled in with mosses.

Place your terrarium in a well-lighted spot, and keep it covered, so that the water loss is small. Add water from time to time, so that the soil remains very wet at the shallow end, and quite moist at the other end. Small turtles, frogs, or salamanders are good bog terrarium animals.

ANALYSIS After setting up and studying a bog terrarium, prepare answers to the following questions in your notebook:

1. Why do you suppose you were advised to plant liverworts on a very wet soil?
2. Suppose algae begin to grow on the inner surfaces of the glass. How can you account for their presence?
3. Do you think this type of terrarium would provide a good place in which to grow young bean plants? Give reasons for your answer.

A WOODLAND TERRARIUM You can set up a woodland terrarium in much the same manner as the preceding. As before, put a layer of sand about an inch thick on the bottom of the container. Cover the sand with three inches of soil from the forest floor. Keep the soil moist, but not wet. Now you are ready to install your plants.

These plants can be any types that are found in partially shaded forest locations. They include various types of mosses, ferns, and club mosses, as well as some small seed plants. A partly decayed branch of a tree, with some fungi growing on it, makes a good addition, as does a stone upon which lichens are growing. Lichens are one of the oddities of the plant world. They form crustlike, greyish-green growths on rock and tree surfaces. Each lichen is really two plants that live together in a sort of partnership. One plant is a fungus, and the other is a food-making alga. See pages 232–233.

Various small animals may be kept, at least temporarily, in a woodland terrarium. In fact, some types probably will come in with the soil you use. Otherwise, the terrarium is a suitable place for a small toad or small salamander.

A DESERT TERRARIUM A desert terrarium provides an interesting contrast. In this case, put about an inch of gravel on the bottom of the container, and cover it with three inches of sandy soil. Now plant such desert species as small cactus plants. Keep them well-watered at first, until their root systems become well-established. Place the terrarium in a well-lighted spot.

Small desert animals, such as various lizards, are appropriate for this type of terrarium. Certain organisms probably will come in with the soil.

PART II: DEMONSTRATIONS AND EXPERIMENTS

The following laboratory experiments are related to the topics in Block II. In Chapter 6, for example, you learned about food supplies of the community. The first three exercises described here have to do with this subject, since they deal with factors that affect food production.

THE RATE OF PHOTOSYNTHESIS

You know that green plants can produce sugar, using water and carbon dioxide as raw materials. When this is done, oxygen gas is given off as a by-product. We call the process photosynthesis.

LIGHT AND PHOTOSYNTHESIS What factors influence the rate of photosynthesis? Certainly, the presence or absence of light should make a difference. But does the brightness or intensity of the light affect the rate at which sugar is produced? And if so, how? This study may help you to answer these questions.

Because oxygen gas is a by-product of photosynthesis, we can use the amount of oxygen released by a plant as a measure of how much photosynthesis is taking place. The aquatic plant, *Elodea,* is useful in this study because it releases oxygen in bubbles as it carries on the food-making process.

Obtain two equal pieces of *Elodea* that are two to three inches in length. It is best to cut the tips from longer stems, using a sharp razor blade, and to do the cutting under water. Weight the uncut ends with bits of metal foil. Put the *Elodea* stems in two tubes of pond water, with the cut ends at the bottoms of the tubes. Now invert the tubes in separate jars of pond water. Keep the water in the two jars at the same temperature by changing the water whenever necessary, or by adding tiny bits of ice to prevent the water from becoming too warm. You will, of course, need a thermometer to check the water temperature.

Place one jar with its *Elodea* in a bright light. Try a laboratory lamp at a distance of about three feet. Place the second jar in a dimly lighted place. After awhile bubbles probably will appear at the cut end of the plant that is brightly lighted. Count the number of bubbles released by the plant during a one-minute period. Repeat this count at least twice, and then calculate the average. Make a similar set of counts while

Lamp distance (in feet)	Number of bubbles per minute			
	Trial 1	Trial 2	Trial 3	Average
3.0				
2.5				
2.0				
1.5				
1.0				

observing the plant that is in dim light.

Move the lamp to a distance of two and a half feet from one *Elodea* plant. Make three one-minute bubble counts, and determine the average. Check the plant that is in dim light again. Repeat this procedure with the lamp at two feet, one and a half feet, and one foot. Summarize your results on a data sheet like the one on page 258.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What effect does light intensity seem to have on the rate of photosynthesis in *Elodea*?
2. Why is it important to control the temperature of the *Elodea* samples in this study?
3. What purpose was served by the second *Elodea* tube?

CARBON DIOXIDE AND PHOTOSYNTHESIS
We can be fairly sure that the amount of carbon dioxide available to a plant in pond water is somewhat limited. If we increase the amount of carbon dioxide around an *Elodea* plant, do you think the rate of bubble formation will also increase?

You can provide more carbon dioxide in pond water by blowing your breath through a soda straw into the water. Another way is to add some 0.5 percent sodium bicarbonate solution to the water.

Plan an experiment to see if an increase of carbon dioxide in the water will affect the rate at which *Elodea* produces oxygen bubbles. Be sure to keep the plants in bright light, and to keep the temperature constant. If your teacher approves the plan, carry out the experiment.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What did you use for a control in your experiment?
2. How did increase in carbon dioxide seem to affect the rate of photosynthesis?
3. Why is it important to keep both light and temperature constant?

COLOR OF LIGHT AND PHOTOSYNTHESIS
The sunlight which green plants receive is made up of radiations that are red, orange, yellow, green, blue, and violet. Yet to us, this sunlight appears "white." If we place a red cellophane sheet between a plant and white light, the red sheet absorbs most of the radiations except red, and the red radiations pass on through to the plant. A green cellophane sheet will absorb most of the radiations except the green. Thus, we can use colored cellophane to filter out various light radiations.

Do you think some sunlight radiations may provide more energy for photosynthesis than other radiations do? We can use *Elodea* and the bubble-counting technique to find out.

Set up two portions of *Elodea* in test tubes of pond water, and invert the tubes in jars of pond water, just as you did in the experiment on page 258. Place both jars at a fixed distance from a strong white light source. Cover one jar with transparent cellophane. Cover the other jar with red cellophane. Determine the average number of bubbles released per minute by the two plants. Repeat the experiment using

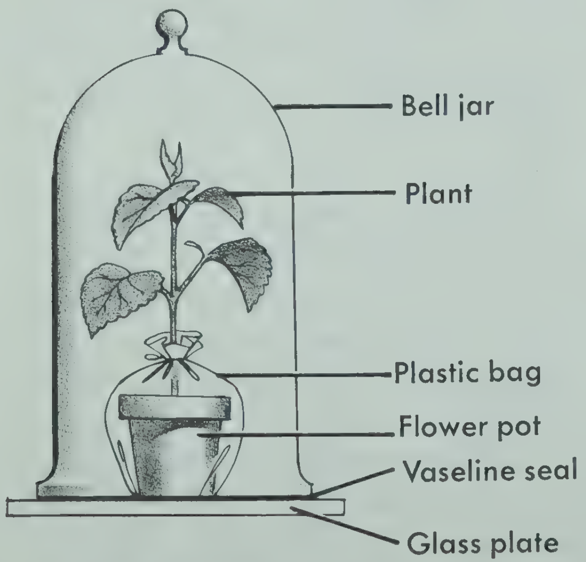
Cellophane color	Bubbles per minute			
	Trial 1	Trial 2	Trial 3	Average
Colorless				
Red				
Green				
Blue				

green cellophane, and again using blue cellophane.

Record the findings in your notebook. Use a data sheet like the one shown above.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What colors of light seem to be most effective in providing energy for photosynthesis? What are your evidences?
2. Some colors of cellophane probably allow more light radiations to pass through than other colors do. In this study, the result might be a major source of error. How could you control this source of error?



L–3. Demonstration of loss of water by a seed plant.

LOSS OF WATER BY PLANTS

In your study of Chapter 6, you learned that leaves have stomata. Through these stomata, leaves receive carbon dioxide from the air. The stomata also provide for the escape of excess oxygen formed in food-making processes. In addition, water in the form of water vapor passes out through these tiny openings. This discharge of water is called ***transpiration*** (*tranz*-per-*ray*-shun).

A TRANSPIRATION DEMONSTRATION Obtain a potted plant like that shown in Fig. L–3, water the soil well, and enclose the flower pot in a plastic bag that is tied securely to the plant stem. Place the potted plant on a glass plate in a well-lighted place. Cover the plant with a bell jar, and use vaseline or some similar substance to seal the rim of the bell jar to the glass plate.

In due course of time, water vapor should condense on the inside of the bell jar to form visible drops. Observe what happens after 24 hours, 48 hours, and 72 hours.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How does the plant obtain the water that is lost in transpiration?

2. What is the reason for enclosing the flower pot and its soil in a plastic bag?
3. Why would a plant, like the one you used, be poorly adapted to life in an area where there are few rains.

HIGHER PLANTS

Your studies of Chapter 6 and Chapter 7 have made it obvious that higher plants provide most of the basic food for animals that live on the land. And some of these plants are very important to human economy. Among them are the ferns, the cone-bearing plants, and the flowering plants.

TYPES OF HIGHER PLANTS Obtain specimens of two or three ferns, small cone-bearers, and flowering plants. Compare their root systems, stems, and leaves. All of them are vascular plants.

In your notebook, prepare a list of things these plants have in common. Prepare a second list to describe ways in which the three types differ.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What is there about these organisms that indicates they should be called plants rather than animals?
2. How do they differ from such plants as algae, molds, and mosses?
3. Why do we call them "vascular plants"?

INVESTIGATING A FACTOR IN PLANT GROWTH There are many factors that affect growth in higher plants. Their spores and seeds are carried about in various ways that you will study later. Some of the spores and seeds end up in places where they can develop into new plants, but others do not. For instance, does it make a difference how deeply a seed is buried in the soil?

To test this, you will need several containers of varying depth. Flower pots, widemouth jars, or milk cartons, with their tops cut off, will prove useful. Fill six of these containers with the same type of loam, and put them on a growing shelf where they will receive sunlight. Soak some pea or bean seeds overnight in water. Then plant four seeds just beneath the soil surface in the first container, four seeds at the depth of *one inch* in the second container, at a depth of *two inches* in the third container, and so on, so that you have four seeds at a depth of *five inches* in the *sixth* container. Add water to the soil in the containers when needed, to keep the soil moist, but not wet. Observe what happens daily, keeping a record in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways did the sprouting and growth of the plants differ from container to container? How do you explain these differences?
2. Why was it important to plant more than one seed in each container?
3. Do you think that other kinds of seeds are affected in a similar way by the depth of planting? How sure are you? How could you check on your ideas?

PLANT FOODS FOR MAN You have learned that all organisms are dependent upon plants for their food supplies.

Man is no exception. Even when we eat animal food such as meat, fish, or eggs, the materials in these foods can be traced back through food chains to the plants.

How many kinds of plant materials do you eat directly? What parts of the plants are used as food? You can make an interesting study of man's plant-eating habits by visiting a local market or grocery store. Examine the fruits, vegetables, and packaged seeds, or seed products. Make a collection of small food samples over a period of time at home.

To describe your food samples, prepare a chart like the following in your notebook.

Name of food	Description	Part of plant
1. 2. (etc.)		

For each food sample, decide whether it represents a root, stem, leaf, flower, fruit, or seed. Some samples may be combinations of plant parts. You may want to cut some samples open, or take them apart in other ways, to see just what is represented. In other cases, you may need to use a reference book to determine what part of the plant is involved.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Are roots, stems, leaves, fruits, and seeds equally represented in your collection of plant foods? Or, does man appear to prefer certain parts? Explain.
2. What is the relationship between fruits and seeds? How would you describe a "fruit"?
3. What seems to be the basis for separating plant foods into "vegetables" and "fruits" in a market?
4. Which kinds of seeds or seed products were most common, the cereal grains, or products from the bean family? Do your findings support the statements made in this book? Explain.

POPULATION CHANGES

One thing you have learned about natural communities is that their populations are continually changing. As some individuals die, new individuals are produced. A species, that is represented by many individuals at one time, may be reduced to a few individuals at another time. This relates to the successions you studied in Chapter 7.

CHANGES IN A LABORATORY COMMUNITY

It is possible to use a tiny laboratory community to study changes of this nature. Fill a small jar about two-thirds full of boiled pond water. Drop in one or two dried pea or bean seeds. Add a drop or two of pond water that is known to contain a variety of microorganisms. Place the jar where it will receive some light and be at room temperature.

Each day for several days, check a drop of water from the jar to see if there has been any change in the number or kinds of organisms present. To do this, stir the water in the jar so that the organisms are distributed fairly evenly. Now remove a sample drop with a pipette, and put it on a

blank slide. Add a cover glass, and view with low power of a microscope. Without moving the slide, count the number of each kind of organism you see in the low-power field of view. Now move the slide and make a second count in a different field of view. Move the slide again, and make a third count.

Prepare a data sheet in your notebook on which to enter the results. Below is a sample which may prove useful.

If you do not know the name of a certain organism, describe or sketch it on your data sheet, in such a way that you will not confuse it with other organisms.

Probably your data will make an interesting graph. You can use time in days as units on the horizontal axis, and number of organisms as units on the vertical axis. Lines of different colors can represent the organisms that appeared in the community.

ANALYSIS Prepare answers to the following questions in your notebook:

1. During the time of your study, did some organisms seem to increase in number, while others decreased in number? Explain.
2. Were larger organisms more numerous at the beginning or at the end of your study? How would you explain this result?
3. Why were the seeds added to the water?
4. Do you have any evidence that suggests food chains operated in your laboratory community? How so?

SOILS AND WATER

In studying Chapter 8, you learned that some soils absorb water more readily than other soils do, and also, that water evaporates more rapidly from some soils than from other soils. You can confirm these conclusions, if you have small samples of gravel, sand, and loam.

WATER ABSORPTION AND WATER RETENTION Pack three widemouth bottles, that hold from 6 to 8 ounces, to within an inch of their tops with (a) gravel, (b) sand, and (c) loam. Use a graduate to see how much water you can add to each bottle without having any water stand above the soil level. In the case of the loam, you will have to add the water a little at a time, waiting until it soaks down into the soil. In your notebook make a record of how much water each soil sample absorbed.

Now place the bottles on a shelf, and observe them from day to day. Find out how long it takes for each soil sample to become dry. Summarize your observations on a data sheet like the one at the top of the next page.

Day	Name or Description	1st Count	2d Count	3d Count	Average
1. 2. Etc.					

Soil	ml of water Absorbed	Days until dry
Gravel		
Sand		
Loam		

ANALYSIS Prepare answers to the following questions in your notebook:

1. Which soil type absorbed the most water? The least? How do you explain these results?
2. Which soil type dried out first? Last?
3. How do you think clay would compare with the soil types you tested? Why?

ACID AND ALKALINE SOILS Some soils, and especially those you find in and about bogs, contain a lot of acid substances and are called ***acid*** or sour soils. Other soils are ***alkaline*** (*al*-ka-lyn) or sweet soils, because they do not contain the acid substances. Some land plants are well adapted to grow on acid soils, and other land plants, including many that we raise, are favored by alkaline soils. Thus, the chemical nature of the soil is a factor that determines what kinds of plants are likely to survive. This relates to our study of soils in Chapter 8.

If you have a small sample of bog soil, you can test it to see whether it is an acid soil or an alkaline soil. Begin by filling a six-ounce beaker half full of water. Add 10 ml of limewater to the water. Now use a pipette to add a drop of phenolphthalein solution. See if the contents of the beaker turn a light pink in color. If not, add phenolphthalein solution drop by drop until they do. The pink color indicates that the liquid is on the *alkaline* side, because you added limewater which is alkaline. If the liquid remained colorless it would be either *acid* or *neutral.*

Now add enough bog soil to the liquid in the beaker to come up to the liquid level. Stir the soil until it is thoroughly wet. Use a funnel and filter paper to filter the liquid from the beaker into a test tube. As the filtered liquid fills the test tube, observe its color. Is it still pink?

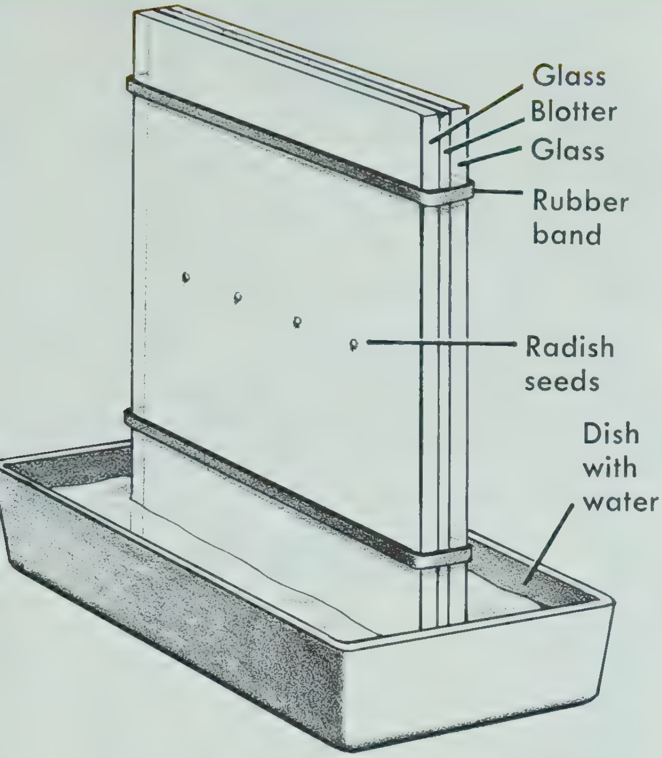
ANALYSIS Prepare answers to the following questions in your notebook:

1. What color was the filtered liquid? Does the result indicate that the soil was acid, or alkaline? Why?
2. In some parts of the country gardeners often add lime to the topsoil. Why do you suppose they do this?
3. Pitcher plants commonly grow in bogs. What does this tell you about the type of soil to which they are adapted?

ROOT GROWTH AND STRUCTURE

After studying habitats in Chapter 8 and adaptations in Chapter 9, you may be interested in some of the factors that affect the growth of roots. For example, do young roots have to be in contact with soil before they will grow toward it? Is root growth affected by gravity? You may be able to answer these questions after making the following test.

SEEDS IN A POCKET GARDEN Place three or four radish seeds on a piece of white blotting paper. Sandwich the seeds and



L–4. Demonstration of direction of root growth.

paper between two pieces of glass. Use rubber bands to hold the "sandwich" together, as shown in Fig. L–4. Now stand the "sandwich" on end in a shallow dish of water. The water will be soaked up by the blotter and will keep the seeds moist. After the seeds have begun to sprout, note the direction of root growth. When the roots have grown about an inch, reverse the "sandwich," so that the opposite end is in the water. After a day or two, check the direction of root growth again.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Does gravity seem to influence the direction of root growth? What evidence do you have?
2. What can be said about the direction of root growth and the location of water in this test? Can you be sure that the results were due to the influence of gravity, rather than the presence or absence of water? Explain.

ROOTS AND WATER How can we test to see if root growth is influenced by the presence or absence of water? One way is to use a pocket garden, but this time it is a pocket garden of a different type.

Begin by soaking some seeds overnight. Put a row of seeds along the center of a glass plate. Arrange a piece of wet blotting paper on one side of the seed row, and a piece of dry blotting paper on the other side of the seed row. Put another glass plate on top to complete the "sandwich." Tape the edges of the two glass plates together to prevent drying.

Place this pocket garden on a shelf or table top. After the seeds sprout, observe the growth of the young roots, and record the observations in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Does root growth seem to be influenced by the presence of water? What evidence do you have?
2. Could the glass sandwich, with the wet and dry blotter, be used to test whether the influence of gravity is stronger than the influence of water? How so?

TYPES OF ROOTS The root systems of various plants are related to survival, a topic which you studied in Chapters 9 and 10. Probably you have noticed that some plants, such as the ferns and seed

plants, have root systems. Did you also notice that plants which lack roots generally grow in rather moist places? On the other hand, many plants that have root systems are able to survive where the surface soil is fairly dry. How would you explain this observation?

You can learn more about root adaptations by examining the root systems of a number of seed plants. Such plants can generally be obtained with ease during the autumn season. Dig them up carefully, and wash away the soil so that the root structures can be seen. A good selection would be a corn plant, a grass plant, a carrot or beet, a dandelion, and a bean plant.

ANALYSIS After comparing the root systems of a number of seed plants, prepare answers to the following questions in your notebook:

1. In what ways are the root systems similar? In what ways do they differ?
2. Why can plants like this survive on a soil where the top two or three inches are often dry?
3. Do you find any suggestion that reserve food materials are stored in some of these roots? Explain.

ADAPTATIONS

You now know that adaptations include a variety of structures. They also include behavior, or the ways in which the structures are used. Thus, the manner in which a starfish opens clams and consumes their fleshy parts has been described in Chapter 9. This is one type of special adaptation, in this case, concerned with obtaining food.

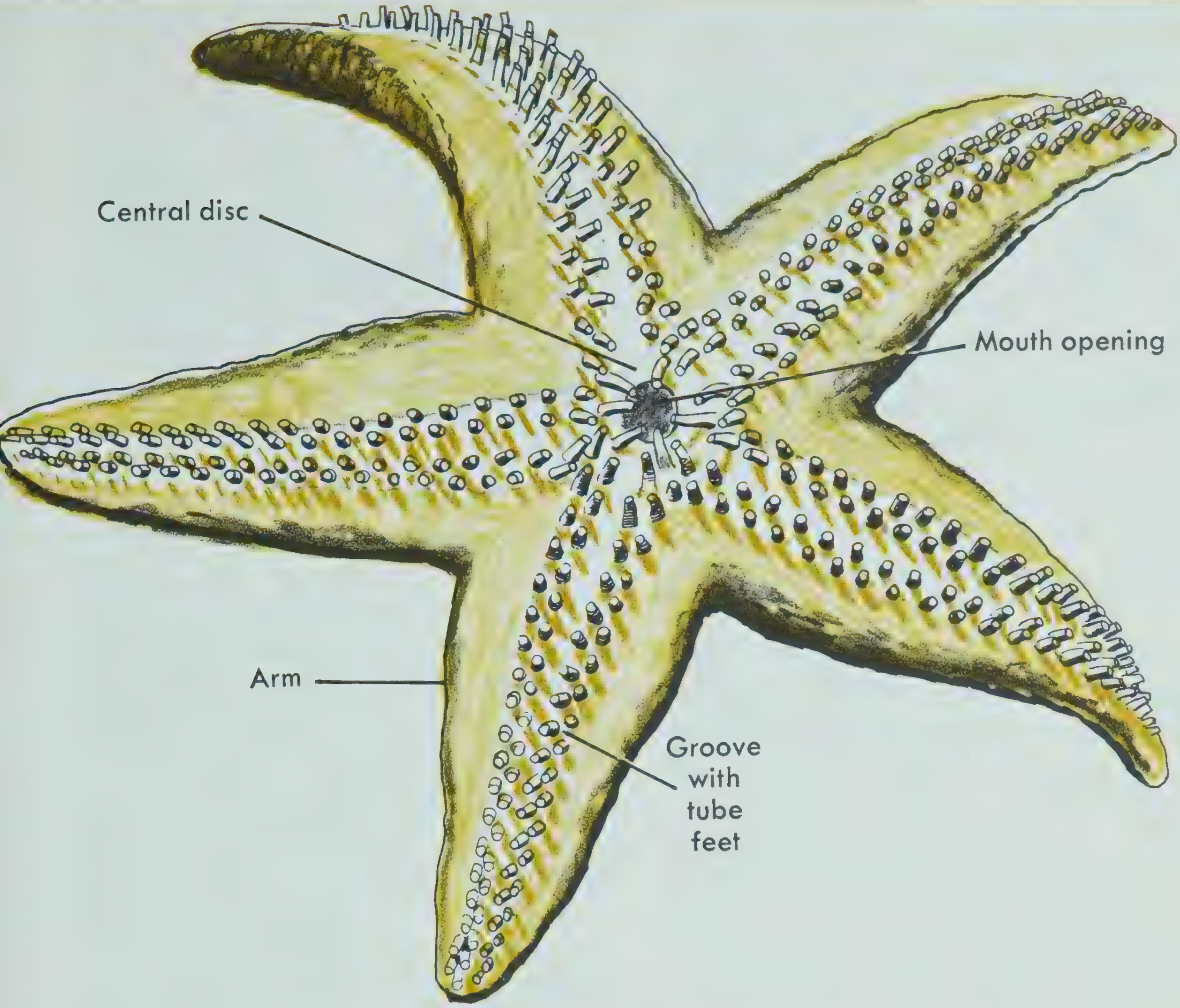
ADAPTATIONS OF A STARFISH Starfishes are not really fish. Rather, they belong to a group of invertebrates that have some unusual structures. This group also includes the sea urchins, sea cucumbers, and brittle stars. All of these animals live in the sea, and some of them can often be collected along beaches. They have skeletons made up of lime plates embedded in their body walls. They also have hard spines, which protrude outward, and are quite large in some of the sea urchins.

Examine a preserved starfish, which can be obtained from any biological supply company. Note that it has a thin, fleshy outer covering. The body consists of a *central disc,* and *arms* which radiate outward from the disc. On the upper surface of the disc, you will find a small, porous, circular area, through which water enters and leaves a system of internal *water canals.*

On the lower surface of the central disc is a mouth opening that can be expanded, so that the animal can force its stomach out of the body as described in Chapter 9. The stomach is a pouchlike structure, that normally occupies much of the space in the central disc. Pairs of digestive glands extend out into the arms, and discharge digestive fluid into the stomach.

On its lower surface, each arm has a groove running its entire length. The tips of the tube feet may be seen in this groove. Fig. L–5 is a diagram of these structures. The tube feet are connected with the internal water canals. They are used to hang on to a clam that a starfish is opening.

Use a sharp scalpel to cut through the mid-region of the animal's arm.



L–5. The lower surface of a starfish. Name some adaptations of a starfish.

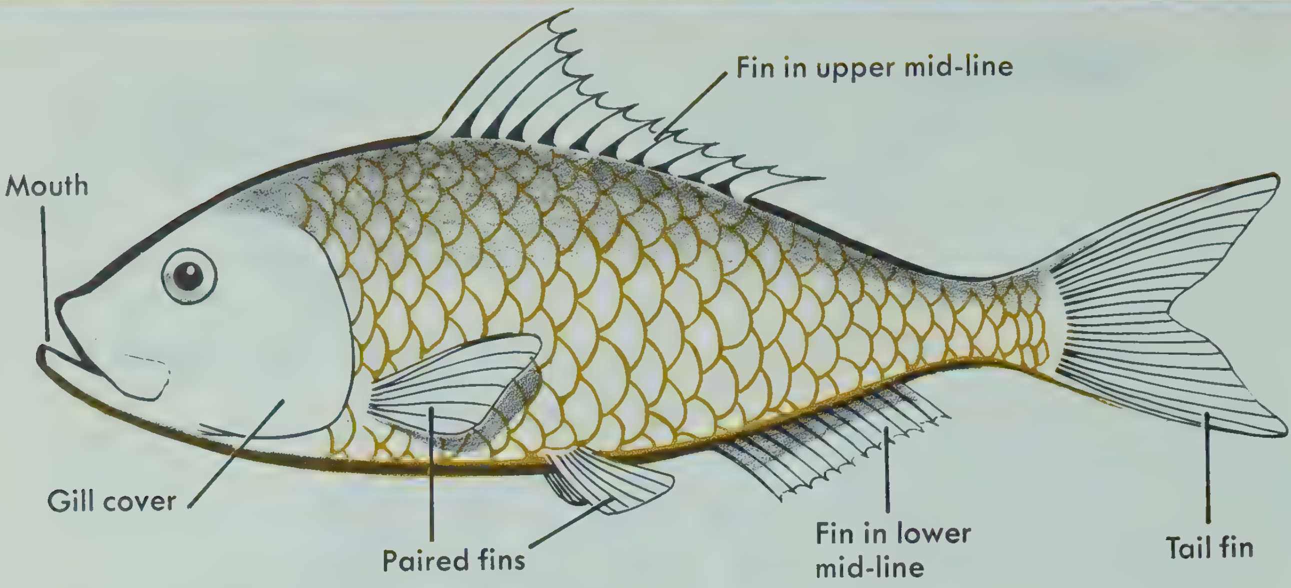
Now you can see the plates in the body wall. You also see the body cavity, and the digestive glands lying in it. You can observe the arrangement of the tube feet, and how their tips extend down into the groove. Note the presence of thin places in the body wall on the upper surface. Gases may enter and leave the body cavity through these areas.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Of what value do you think spines may be to starfishes and their relatives?
2. What is the advantage in being able to thrust the stomach out of the body through the mouth opening?
3. Why do you think that the digestive glands are important to this animal?

ADAPTATIONS OF A FISH Among the adaptations possessed by an organism are those that enable some species to live in the water. Gills, for example, make it possible for some animals to obtain oxygen from air dissolved in the water.

Observe a small, living fish in a battery jar of water, or in an aquarium. Fish are not all alike, but probably your



L–6. External structures of a fish.

specimen will have a fairly large tail fin, and another fin along the mid-line of its back. It may also have a small fin along the mid-line of the lower surface, a short distance in front of the tail. It will have a pair of fins—one on each side of the body—just behind the head, and another pair farther back along the lower side of the body. These fins correspond to the limbs of other vertebrates.

Probably the fish you observe will be gulping mouthfuls of water all the time. This water flows between its gills, which are hidden by *gill covers* on each side of the head. The back margins of the gill covers can be lifted to let the water escape, after it passes through the gill regions. Fig. L–6 shows the mouth, gill cover, and fins of a fish.

Observe how the fish swims for a few minutes. How does it use its fins? Tap the side of the aquarium with a pencil and see how the fish reacts. Tap the surface of the water and observe the result. If you have a small flashlight, see how the fish is affected by a small, bright beam of light.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways is a fish well adapted for life in the water?
2. To keep on living, a fish must have an oxygen supply. Explain how a fish gets this oxygen?
3. In what ways did your fish react to things that happened in its surroundings?

GROWTH AND LIFE CYCLES

In studying Chapter 11, you learned some things about life cycles. Very young plants and animals usually are quite small. This means that growth must take place before they can become adults. So growth is a feature of life cycles.

You have probably seen plants sprout and grow. You may have observed how young kittens and puppies grow and develop into adults. Are the growth patterns of plants and animals similar? How does the environment affect these growth patterns?

INVESTIGATING GROWTH IN PLANTS It is fairly simple to study the growth patterns of some plants. To do this, soak a number of pea or bean seeds in water overnight. Plant half of them in one flat, and half in another flat. Have rich loam soil, to which fertilizer has been added, in *flat A*. Have a mixture of sand and loam with no fertilizer in *flat B*. Water the flats regularly so that the soil remains moist, but not wet. Keep them on a growing shelf where the plants will receive plenty of sunlight.

Select the first 10 plants that sprout in each flat for study. Discard the remaining plants. Three days after the last plant has sprouted, measure the stem lengths of the plants in *flat A* and in *flat B*. Compute the average length for each flat. Repeat the measurement every third day for two or three weeks. Prepare a data sheet in your notebook like the one shown below and enter your findings.

Prepare a graph of your data for each flat. Use time in days as units on the horizontal axis, and average stem length as units on the vertical axis.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did the plants seem to grow at a constant rate, or more rapidly at certain ages?
2. Was the rate of growth the same in *flats A* and *B*? If there was a difference, how do you explain it?
3. Did all of the plants in *flat A* grow at the same rate? If not, how do you explain the difference?

INVESTIGATING GROWTH IN ANIMALS Make a similar study of growth using an animal. Be sure to start with a young animal that can be raised successfully in the laboratory.

A young frog makes a good subject. It can be kept in the school terrarium. For food you will need mealworms, which you can get from a biological supply house. Then you can raise your own mealworms in a battery jar that contains torn up scraps of paper and two or three ounces of oatmeal. Another possible subject is a young tadpole, that you raise in an aquarium. Feed it as you would feed a fish.

Keep records of the animal's length. If a balance is available, record the animal's weight. Make your readings every third day. Meanwhile, be sure that the animal receives all of the food it will eat each day.

Prepare a graph of your data, as you did in the case of the plant-growth data. Graph the length and the weight on separate pieces of paper.

Flat	Day	Lengths of stems	Average Length
A	3		
A	6 (etc.)		
B	3		
B	6 (etc.)		

ANALYSIS Prepare answers to the following questions in your notebook:

1. Was the growth of the animal uniform, or did the animal appear to grow more rapidly at certain times?
2. Can you see any similarity in the growth patterns of the plants and the animal that you studied? How so?
3. In what ways would it have been better to have several animals of the same age and species for this observation?

GROWTH OF THE HUMAN BODY Does human growth follow a pattern similar to the other organisms you have studied? Humans, of course, grow too slowly for us to get measurements in a few days or weeks. We can, however, study some data that a student of the subject has obtained. The following figures represent the average weight and height of a group of boys as they grew from birth to 18 years of age.

Prepare a graph of this data, using years as the units on the horizontal axis, and weight in pounds as the units on the vertical axis. Prepare a second graph using height in inches as the units on the vertical axis.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways is the growth pattern of these boys similar to that of other organisms you have studied?
2. Is the graph of human growth in terms of height similar to the graph in terms of weight? How so?
3. Biologists often refer to the lines of growth data on graphs as being "S" shaped. Can this idea be applied to any of the data that you have graphed? Explain.

LIFE CYCLE OF A FRUIT FLY Adult living fruit flies can be obtained from biological supply houses. Young flies can be raised in the laboratory, so that their life cycle can be observed.

First, prepare an agar-banana medium. Stir 1.5 grams of agar into 48 cc of water. Bring the mixture to a boil. Now add 50 grams of overripe, mashed banana, and heat to the boiling point again. Spread some of the resulting medium over one side of a blank slide.

Age (years)	Weight (pounds)	Height (inches)	Age (years)	Weight (pounds)	Height (inches)
Birth	7	20	10	80	55
1	24	30	11	85	57
2	30	35	12	95	59
3	34	38	13	105	61
4	40	42	14	115	63
5	45	45	15	125	66
6	50	47	16	135	67
7	55	49	17	145	68
8	65	51	18	150	68
9	70	53			

Place the slide in a widemouth bottle. Put a wad of damp paper toweling in the bottle to provide moisture. Now put several adult fruit flies in the bottle, and plug the opening with a wad of cotton. Any females among your fruit flies will soon lay eggs on the coated slide. After two days you can release the adult flies, and examine your slide under the low power of a microscope.

Then return the slide to the bottle. Keep the bottle and its contents at room temperature. See what happens every day for about two weeks. A fruit fly has a life cycle similar to the moth you studied on page 241. Record observations in your notebook from day to day, using sketches to represent changes in the developing flies.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What stages were represented in the life cycle of the flies you studied?
2. How long did it take the flies to complete their life cycles?
3. What environmental factors do you think may influence the flies' rate of growth? How could you test your ideas?

PART III: INVESTIGATING A LAND COMMUNITY

If you wish to study a land community, the first problem is to select a suitable area. Almost any piece of land will provide some opportunities for making observations. A vacant lot, a backyard, a plot of grass, a lawn, or a woodlot will serve. One of the better possibilities, however, is provided by a meadow that is traversed by a small stream, and bordered by trees or bushes.

Next, you have to decide how much of the area you are going to study. If the space available is only a few square yards in size, you may want to use all of it. On the other hand, you would not be able to study more than a small part of a forest or meadow. Probably you will want at least 5 square yards of space, and not much more than 20 square yards. It may help to mark off the area with stakes and string, so that you have definite boundaries in which to make your observations.

MAPPING THE AREA Make a detailed map of the area selected. Be sure to indicate the size of the area, and the location of trees, shrubs, rocks, and similar features. Also, indicate where smaller types of plants, such as grasses, mushrooms, mosses, ferns, and lichens are found. If the area is not level, you may want to prepare a cross-section map, to show the slope of the land and the high and low places.

STUDYING PHYSICAL FACTORS OF THE AREA While making a study of the physical factors in the area, you will need a notebook at all times. It is important to record your observations as soon as they are made. Record the date, time, and location of each observation.

1. Make a careful study of the temperature in the area. Check the air temper-

ature in a sunny place and in a shady place. Find the temperature of the surface soil in the sun and in the shade. Then check the temperature an inch or two beneath the soil surface in the sun and in the shade. If there are rocks in the area, check the temperature beneath them. If possible, repeat these measurements at different times during the day, such as 8 A.M., 10 A.M., noon, 2 P.M., 4 P.M., 6 P.M., 8 P.M., and 10 P.M.

2. Humidity refers to the amount of water vapor in the air. Warm air can hold more water than cold air. *Relative humidity* is the amount of water vapor in the air compared with the amount of water vapor the air can hold at that temperature. Thus, if the relative humidity is 50 percent, the air contains half of the water vapor that it can hold at the existing temperature. One of the easiest ways to find the relative humidity is to use a wet- and dry-bulb thermometer. To do this, you need a pair of thermometers. The bulb of one of them is kept wet by wrapping it in a bit of loosely woven cotton cloth, and allowing one end of the cloth to extend down into a small container of water. The two thermometers are read at the same time. From these readings, the relative humidity can be determined by using a chart such as the one shown below. If possible, determine the relative humidity of the air in the study area, several times during a 24-hour period.

3. You will want to study a number of soil factors in your area. For example, what percentage of the weight of a soil sample is due to water? You can find out by weighing a soil sample, drying it, and then weighing it again. The soil

Relative Humidity Table

	Difference Between Dry- and Wet-bulb Thermometers in Degrees														
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Dry-bulb Thermometer	*Percent Humidity*														
63	95	89	84	79	74	69	64	60	55	51	46	42	38	33	29
64	95	89	84	79	74	70	65	60	56	51	47	43	38	34	30
65	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31
66	95	90	85	80	75	71	66	61	57	53	49	45	40	36	32
67	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33
68	95	90	85	81	76	71	67	63	58	54	50	46	42	38	34
69	95	90	86	81	76	72	67	63	59	55	51	47	43	39	35
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36
71	95	91	86	81	77	72	68	64	60	56	52	48	45	41	37
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
73	95	91	86	82	78	73	69	65	61	57	53	50	46	42	39
74	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40
75	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40

can be dried by placing it in an oven at low heat for several hours. You can compute how much water was in the soil by using the following formula:

$$\frac{\text{weight lost}}{\text{original weight}} \times 100 = \text{percentage of original weight that was water}$$

Determine the percentage of water in a soil sample from the study area. If the soil varies from place to place within the area, check the percentage of water in samples from several locations. Record the findings in your notebook.

How much water can a soil sample hold? To find out, dry a sample of soil in an oven, weigh the sample, and place it in a funnel on top of some filter paper. Using a graduate, measure out a quantity of water. Pour the water from the graduate onto the soil until the soil is wet, and water begins to run through the funnel. Catch the water that comes through the funnel, and return it to the graduate. Now calculate how many milliliters of water was held by the soil in the funnel. Then calculate the milliliters of water held by each gram of dry soil, using the following formula:

$$\frac{\text{milliliters of water held}}{\text{weight of soil in grams}} = \text{ml of water per gram of soil}$$

Determine the water-holding capacity of a sample of soil from your area. If the soil seems to vary from place to place, check the water-holding capacity of soil from several locations. Record your findings in your notebook.

As you know, *humus* is present in many topsoils. It represents the decaying remains of plants and animals. These remains are organic and can be burned. We can determine what percentage of soil weight is due to humus by weighing a *dry* sample, and then heating it to a temperature that will burn away the humus. You may want to heat a soil sample in a can over an open burner flame, or in an oven set at high heat. The soil should be stirred several times during the burning process, so as to bring all of the humus in contact with the air. After burning the humus away, let the sample cool, and then reweigh it. The percentage of humus can be calculated by using the following formula:

$$\frac{\text{weight lost}}{\text{original dry weight}} \times 100 = \text{percentage of original weight due to humus}$$

Determine the humus content of soil from one or several places within the study area. Record the findings in your notebook.

The *soil pH,* as indicated on page 264, refers to the acid-alkaline condition of the soil. The pH scale runs from a value of 1 to a value of 14. The neutral or middle point is pH 7. A pH lower than 7 is *acid,* and a pH higher than 7 is *alkaline.* There is a 10-fold difference between each pH value. Thus, pH 5 is ten times more acid than pH 6, and pH 12 is ten times more alkaline than pH 11. One of the easiest ways to find out if a soil sample is acid or alkaline is to use litmus paper. This paper has a dye in it that turns *red* in contact with acid surroundings and *blue* in contact with alkaline surround-

ings. It also is possible to buy pH paper from supply houses that will turn any one of several colors depending upon the pH of the sample being tested. So litmus paper can indicate whether a substance is acid or alkaline; pH paper can also indicate how acid or alkaline the substance is.

To test a soil sample using either litmus or pH paper, the soil must first be moistened with distilled water that has been boiled and cooled. Then the paper is brought in contact with the soil, until the paper is moistened. In the case of pH paper, the resulting color is matched against a color scale, that comes with the paper, to determine the pH of the test sample. Check the acid-alkaline condition of soil samples from several locations in the study area. Include different types of soil. Record the findings in your notebook.

Light is another physical factor of the environment. *Light intensity* can be measured at any spot by using a photographer's light meter. If one is available to you, take readings of light intensity in the study area. If the area includes a variety of shaded sections, measure the light intensity in each of them. Now select one spot for special attention. Measure the light intensity in this spot every hour or two during a clear day. Summarize the findings in your notebook. Graph the data, with time in hours on the horizontal axis, and units of light intensity on the vertical axis.

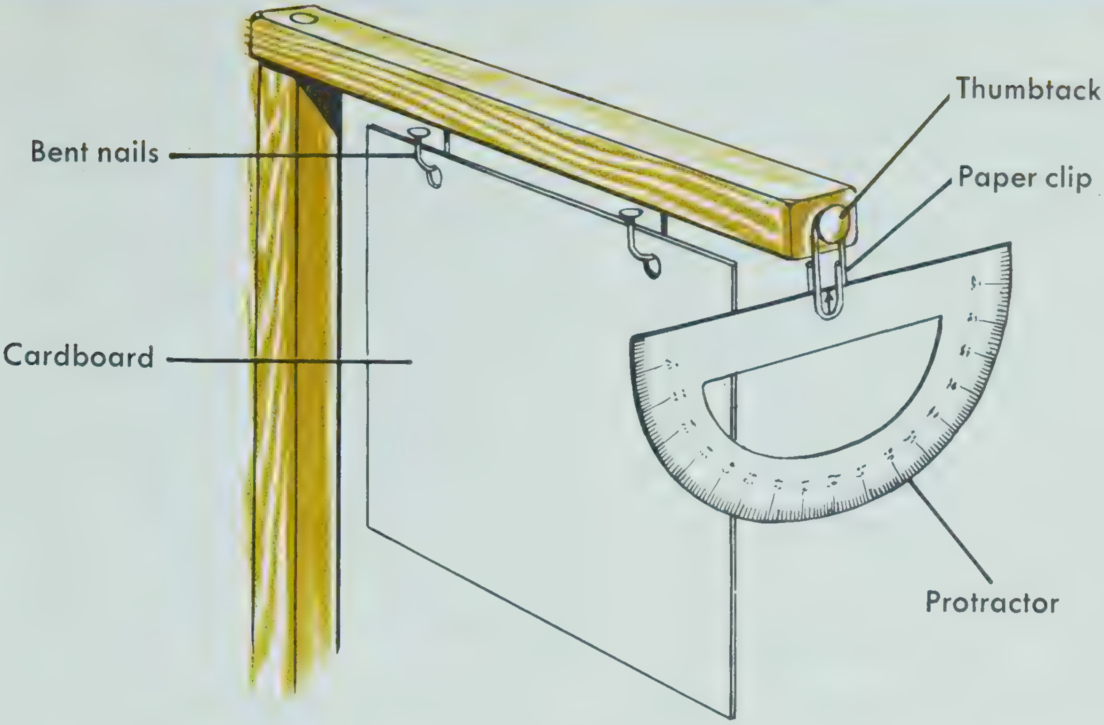
If the area you are studying is subject to regular *wind* or *air movements,* plot the path of the moving air on an outline of your map. Find out if the air movement changes direction or force during a 24-hour period. A simple instrument to measure the force of moving air is shown in Fig. L–7. To build it you need a piece of cardboard, two small pieces of wood, some nails, and a protractor. As the wind blows, the freely swinging piece of cardboard will move out from the stake at an angle. The greater the angle, which you read on the protractor, the greater the force of the moving air.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Which physical factors of the environment tend to vary most widely during a 24-hour period? Least widely?
2. What evidences do you find to support the statement that "The environment is changing constantly"?
3. What evidences do you have that the environment is not the same in all parts of the study area?

COMPARING LAND AND WATER ENVIRONMENTS After you have made a study of the physical factors of a land area, it is interesting to compare these factors with those of a water environment. For example, how does the temperature of a land environment differ from that of a water environment nearby? In which environment does the temperature vary most in a 24-hour period? How does the availability of water differ in the two environments? The availability of oxygen and carbon dioxide? How does the pH of the two environments differ? How do light intensities differ?

If the area you are studying includes a small stream, you can get an-



L–7. Instrument used to measure wind force.

swers to these questions. One suggestion is that you write a brief report comparing the conditions under which a pond snail and a land snail live.

STUDYING HABITATS Are environmental conditions the same throughout the area you are studying? By this time, you know that they are not. Conditions on the surface of the soil are different from conditions beneath the soil surface or under a rock. Conditions on the north side of a tree may be different from those on the south side. Because conditions vary within an area, living things have several different kinds of places to live. As you have learned, the place where a species usually is found is called its habitat. How many different kinds of habitats exist in the area you are studying?

Prepare a list of habitats that you can identify in the study area, and describe the conditions you think exist in each one of them. For instance, you may find living things under a rock. The environment under the rock might be described as moist, dark, protected from wind, and somewhat protected against high or low temperatures.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What evidences do you have that physical conditions vary more on the land than in the water?
2. What determines whether an organism will live on the land or in a water habitat?
3. In what kind of habitat would you expect to find mosses growing? Why?

SURVEYING THE PLANTS OF A LAND COMMUNITY The next step in your study of the area might be to see what

kinds of living things are represented there. Plants are often the most conspicuous types, and the easiest to observe, so you may want to begin with them.

Some of the plants in the study area are too small to be seen. Such types include some of the algae and fungi, and all of the bacteria. For purposes of study, the plants that you can see may be divided into the following groups:

Algae	Club mosses
Fungi	Horsetails
Liverworts	Grasses
Mosses	Trees
Ferns	Other seed plants

You will find descriptions of these groups in Chapter 5 of this book.

It is not necessary to know all of the different plant species. For each of the types in the preceding list, observe whether it is abundant, common, appears occasionally, or is rare within your area. On an outline map of the area, show the locations of each type. Be able to state what sort of habitat appears most favorable for each type.

Your teacher will advise you whether it is possible to collect specimens or samples of some of the plants. If so, you may be able to preserve them for future study in the classroom. After a plant specimen has been collected, it should be placed between single sheets of newspaper. Arrange the plant in a suitable position, so that its parts may be seen. Then place a large blotter on either side of the newspaper containing the specimen. Repeat this procedure until several specimens have been prepared, and stacked one above another. Then place the stack of specimens between flat boards or heavy sheets of cardboard. Apply pressure to the stack by placing a weight on top of it. Or, belts may be placed around the stack and pulled tight, to produce what is called a *plant press.*

For the first few days, the press must be opened daily, and the moist driers removed and replaced by dry ones. Then the moist driers can be dried by placing them in the sun, or in an oven set at low heat. Most plant specimens will be dry within a week or ten days. But during that time the driers must be changed three or four times; otherwise, the specimens may tend to mold and decay.

When dried, the specimens may be fastened to heavy paper with tape or adhesive. The lower right-hand corner of the mounting sheet is reserved for labeling. This should include the plant's common name, scientific name, the location where it was collected, and the date when it was collected.

Some plant tissues are moist and fleshy, and are difficult to dry in a plant press. Such specimens may be preserved in widemouth bottles that contain 70 percent alcohol or 4 to 6 percent formalin (see page 111).

ANALYSIS Prepare answers to the following questions in your notebook:

1. What types of plants appeared to be most common on moist soil in the area? On dry soil?
2. Did any fungi appear in the area? How would such fungi obtain foods?
3. To what extent did your observations support the conclusion that, "Seed plants are the principal basic food makers on land"?

WEED DENSITY Any plant considered undesirable is called a weed. Weeds may be undesirable simply because they have no known use, or they may disfigure a garden or farmland. In other cases, weeds harm crop plants by shading them or by removing soil moisture. In any event, man considers weeds as plant pests and spends a great deal of money and effort to destroy them.

You may be interested in determining the number of weeds growing in your study area. To do this, select a sample of your study area. Mark off a square foot with stakes and string. Then carefully count the plants growing in the area. Also count the number of each kind of plant in your sample. If the plants are still young, you may want to make a similar count of the same area some weeks later. In this way, you can find what proportion of the young plants survive.

Another approach to this type of study involves returning a sample of soil to the laboratory. The soil is placed in a planter and watered. In this way, seeds may be stimulated to sprout, and the number of weeds can be counted. If you follow this procedure, you may want to study soil samples from several locations and compare results.

ANALYSIS Prepare an answer to each of the following questions in your notebook:

1. How many weeds did you find growing in a square foot of soil? How many kinds of weeds were represented? Which kind seemed most successful? How so?
2. Assuming your count was representative of all larger areas nearby, how many weeds could be found in an acre? A square mile?
3. The number of weeds per square foot of soil probably varies from place to place. What factors affect the distribution of weeds? What evidence do you have?

SURVEYING THE ANIMALS OF A LAND COMMUNITY The animals in your study area may be harder to find. Many of them will be under rocks, leaves, or down in the soil. Search the area carefully, and record the animal types you find, and the places where you find them. As in the case of the plants, some of the animals present will be too small to see. But you are likely to find representatives of the following groups:

Worms	Amphibians
Mollusks	Reptiles
Crustaceans	Birds
Insects	Mammals
Arachnids	

You will find descriptions of these groups in Chapter 5 of this book.

Record what the animals seem to be doing, and anything else you observe. You may want to plot the location of the animals on an outline of your map. Some forms of animal life are ***nocturnal*** (nock-*tur*-nul); this means that they seldom come out of hiding except at night. If possible, visit the area after dark, armed with a flashlight. Plot the location of the animals you observe on another outline of your map.

Large forms of animal life, such as birds and mammals, usually occur in small numbers and should not be collected. But you may want to collect some crustaceans, insects, and arach-

nids for future study. Such specimens can be preserved in widemouth bottles containing 70 percent alcohol or 5 to 10 percent formalin. The location and date should be kept for each specimen.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What food groups (herbivores, carnivores, omnivores, parasites) were represented among the animals you observed? List examples of each group.
2. What kinds of animals were found under rocks and leaves, or in other hiding places? Do you have evidences that any of these types are nocturnal? Explain.
3. What representatives of the vertebrate group were observed in the area? How do they affect the invertebrates that live in the area?

COMMON PESTS Take a walk through your study area, and see how many different kinds of pests you can locate. Also notice evidence of pests at work. Keep a record of your observations.

Look carefully at the undersides of plant leaves for insects and molds. Check the surfaces of stems and the inner parts of flowers and flower buds. You may want to uncover a few roots and search for evidence of fungus and damage by worms or insects. Larval forms may be seen in or on fruit and seed pods.

You may find termites living in pieces of wood that have been in contact with moist soil for some time. Ant nests may be common. Land snails and slugs live in moist areas beneath plant cover or under dead leaves. Pill bugs may also be found in such debris. Despite their name, pill bugs are small crustaceans. Of course, the snails, slugs, and pill bugs may not be pests.

Look for evidence of rodents. You may see the entrance to a ground squirrel burrow or trails in the grass made by field mice.

If you can capture a fish or an amphibian, check the skin for external parasites. Dogs and cats may have external parasites too, as do birds and other vertebrates.

If you have the opportunity, survey an area before and after it is sprayed with insecticide or other pest poison. However, such chemicals are very dangerous and should be handled only by qualified adults.

ANALYSIS Prepare an answer to each of the following questions in your notebook:

1. What have you discovered about pests in your study area?
2. Did the pests seem to be well controlled? How so?
3. What animal pests might be found in a house? Where would they probably be found?
4. What problems may be created by excessive use of pest poisons?

STUDYING SOIL ORGANISMS Because it is not possible to search all of the soil in your area without upsetting the community that exists there, it is best to study small samples. A space about 4×4 inches will be large enough to serve as a sample. If there are leaves or other debris on the surface, remove this material. Place it in a container, such as a paper bag, so that you can take it

back to the classroom. Now remove soil to a depth of six inches, and place it in the bag also. If the area you are studying is large, or includes a variety of soils, you may want to check two or more samples.

Back in the classroom, put the soil sample on a large piece of white paper. Loosen the soil so that you can search through it easily. A small magnifier may aid you in locating some of the specimens. Using a forceps, pick out any organisms or parts of organisms you may find. Many of them are likely to be small animals. But plants such as molds, and plant parts such as seeds are likely to be present. You can preserve any of these specimens in 70 percent alcohol or 5 percent formalin.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What kinds of organisms did you find in the soil samples?
2. What kinds of organisms were most numerous? Least numerous?
3. If you checked several samples, did the kinds of organisms differ among them? Explain.
4. Assuming that your samples were representative, calculate how many individuals of two or three types must be present in the top six inches of soil within the study area. In view of what you find, would you say that there are few or many organisms in the surface soil?

INVESTIGATING INTERACTIONS AMONG ORGANISMS Whenever one type of organism does something that aids another type, and vice versa, we say that the two types are interacting positively. If there are any fairly moist places in the study area, you are likely to find some lichens growing there. Often lichens are on rock surfaces or tree trunks. Each lichen, and there are many types, consists of two plants that live together. One of these plants is a fungus, and the other is an alga. The fungus cannot make food, but it can adhere to a rock surface and absorb the water that is needed by both plants. The alga carries on the food-making process, which meets another common need. Thus, both plants of a lichen profit by the association.

If there are any clover plants, or other members of the bean family, such as alfalfa, beans, or peas in the study area, you may be able to observe another type of interaction. The roots of such plants often have tiny nodules on them, as described on page 247. Inside of these nodules are large numbers of nitrogen-fixing bacteria. As you know, these bacteria can change nitrogen of the air into nitrates, that can be used by plants, as they manufacture proteins. Most plants cannot use the pure nitrogen of the air, but they can use nitrates. To a large extent, such plants are dependent upon certain bacteria and algae to make nitrates for them.

See if you can find any nodules on the roots of clover plants in the study area. Before you try to dig up a plant, be sure that the soil around it is moist. Then dig the plant up carefully, so that as many of its roots as possible are saved. Wash the excess soil off the roots, and examine them to see if nodules are present. Nodules look like small lumps, and sometimes you find a lot of them. If you fail to find any

nodules, check a few plants growing outside the study area before you decide that no nodules are present in the community. Record your findings.

Some other types of interactions among organisms are negative. For instance, the deep shade produced by a group of forest trees may keep many small plants from growing beneath them. These small plants do not receive enough sunlight in such a situation. Similarly, if grazing animals feed in a meadow, many young trees are likely to be eaten before they are more than a few inches in height. Look for examples of such interactions.

Biologists have noted that some kinds of plants seldom have other kinds of plants growing beneath or near them. This observation led to the discovery that some plants produce chemicals that inhibit or prevent the growth of other plants. Sometimes the chemicals are formed in leaves, and then carried into the soil by rain water. Such chemicals may inhibit the sprouting of seeds or the growth of seedlings. What advantage would this be to the plant that produced the chemicals? Are there any plants in your area that seem to have few plants growing near or beneath them? If so, you may want to check the soil for the presence of inhibiting chemicals.

To do this, use some grass, lettuce, or tomato seeds as your test organisms. Collect some topsoil from beneath the plant that you think may be producing chemical inhibitors. Collect some similar soil at a spot some distance away from the suspected plant or any other plants of the same kind. Prepare flats of the two soil samples, and plant your test seeds in them. Keep the environmental conditions the same for each flat: the same amount of light and water, and the same temperature. Check the results each day for a period of time. Observe sprouting time, and the growth of seedlings.

Now that you have observed the plants and animals in the study area, you may be able to summarize some of the interrelationships that exist in a land community. You know in advance that the green plants make their own foods. Perhaps you noted that a certain insect feeds upon a particular kind of plant, or that a certain kind of insect is eaten by spiders or birds. But you can hardly hope to know how all of the organisms in the study area obtain their foods. You can, however, find answers to many of your remaining questions in reference books. Then you may wish to prepare a chart which lists types of organisms in the study area which belong to the following food groups:

food makers	omnivores
herbivores	parasites
carnivores	saprophytes

ANALYSIS Prepare answers to the following questions in your notebook:

1. To which food group do you think a lichen should be assigned? Why?
2. If no nodules are found on the roots of clover plants, does this mean that the soil contains no nitrates? Explain.
3. What evidences have you that green plants compete with one another for sunlight? Does this competition have any relationship to the succession described on page 170? Explain.

SUMMARY: BLOCK II

Plants and animals live in communities that are more or less separated from one another by natural barriers. In the sea and in fresh water, the algae are the principal food makers of these communities. On land, the bulk of the basic food is made by seed plants.

Available food supplies vary with changes in the seasons. They may also vary from one year to another. In the seed plant, these foods are produced through the combined activities of leaves, stems, and roots. The leaves are usually the main food-making centers, while the roots absorb water and mineral compounds from the soil, and the stems hold the plants up in contact with sunlight, and serve as pathways for fluids.

The food groups of any community include the food makers, herbivores, carnivores, omnivores, parasites, and saprophytes. Complex food chains exist, in which the materials produced by the food makers are passed along from one organism to another. When food chains are disrupted, many organisms in the community may be adversely affected.

Successions take place in community life, and a species, which is abundant at one time, may be far less common at another time. Plant successions lead to the development of climax populations and balanced communities. When there is a balance in nature, no food group is unduly large.

Physical factors of the environment have important effects upon organisms. Among these physical factors are sunlight, temperature, the presence or absence of water, high and low pressures, and various types of soils. Most organisms exist at or near the earth's surface, where physical conditions favor their survival.

All plants and animals exhibit adaptations, which are concerned with both structure and behavior. Many of these adaptations, such as cyst formation or hibernation, are related to survival. Some adaptations, like the beaks of birds or the teeth of flesh-eating mammals, serve in the procurement of food, but can also be used for defense. Other adaptations are associated with the manner in which the plant or animal reproduces.

There are a number of adaptations that are concerned with flight. Many insects and birds, and a few mammals are able to fly. These animals have wings, but their wing structures are developed in different ways.

Some organisms live in social groups that include castes, such as fertile females, fertile males, workers, and soldiers. Termites, honeybees, and ants develop such societies. Communication is important whether an animal is social or not, and it is achieved in various ways. Higher animals often have warning cries, or other sound signals that indicate distress or the discovery of food. Honeybees engage in two types of "dances" to inform other bees of a food find.

There are numerous examples of mutualism in nature, in which two organisms of different species are associated with benefit to both of them. There are also a good many other associations in which two species are commensals. In the latter type of association, one species generally profits to some extent, but not at the expense of the other species.

The life cycles of organisms include periods of youth, maturity, and old age. Upon death, the decay processes set in. Decay is largely brought about by certain bacteria and fungi. Products that come from the decay of plants and animals are returned to the soil, the water, and the air.

The nitrogen cycle is closely related to the decay of protein compounds. In a never-ending process, nitrogen from the air is combined with other elements to form compounds that plants and animals can use in building proteins. When the plants and animals die, protein compounds are broken down, and free nitrogen is returned to the air.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column. Write in the statement from the second column that goes best with each of the words.

1. agar	A by-product of photosynthesis.
2. humus	Process by which water is lost from a plant.
3. light	Decaying plant and animal material.
4. oxygen	Energy source for photosynthesis.
5. succession	Material used in fruit-fly culture medium.
6. transpiration	Population changes in a natural community.
7. carbon dioxide	A raw material for photosynthesis.
8. nocturnal	Organisms that come out at night.

SELF TEST

For each of the following statements, select the best ending and write it beside the number in your notebook.

1. A bog terrarium would provide favorable conditions for (a) carnivorous plants; (b) cactus plants; (c) grasshoppers; (d) *Elodea.*
2. A freshwater aquarium would provide favorable conditions for a (a) starfish; (b) toad; (c) lichen; (d) *Sagittaria.*

3. A woodland terrarium would provide favorable conditions for a (a) lichen; (b) crayfish; (c) liverwort; (d) *Cabomba.*
4. A balanced aquarium is one in which (a) fresh water is used; (b) animals are fed just enough food; (c) plants are not needed; (d) everything would keep on living even though the aquarium was sealed up.
5. A bog terrarium should contain soil that is (a) dry and acid; (b) moist and acid; (c) dry and alkaline; (d) moist and alkaline.
6. Lichens are plant oddities in that they are (a) seldom seen; (b) always found growing on rocks; (c) made up of two different kinds of plants living together; (d) animal-eating plants.
7. A desert terrarium should (a) be drier than a bog terrarium; (b) contain no plants; (c) contain no animals; (d) never be watered.
8. The quantity of oxygen given off by a green plant, in a certain amount of time, can be used as a measure of the rate of photosynthesis because (a) all plants give off oxygen; (b) plants carry on photosynthesis during the daytime; (c) oxygen is given off only when food is being made; (d) photosynthesis is influenced by the brightness of light.
9. When an investigator studies population changes in a microscopic community by removing a drop of material from a culture and counting the number of each kind of organism present, he assumes that (a) many organisms will be observed; (b) the drop removed is representative of the whole community; (c) the larger forms are eating the smaller ones; (d) the population will change the same way in every microscopic community.
10. Starfish open clams by holding on to their shells with (a) powerful jaws; (b) a central disc; (c) a pouchlike stomach; (d) tube feet.
11. Which of the following is the best example of a way fish are adapted for life in water: (a) the two pairs of fins correspond to the limbs of other vertebrates; (b) fish often eat plant material; (c) fish are sometimes attracted to light; (d) an eye is located on each side of the fish head.
12. Relative humidity is a measure of (a) the amount of water in soil; (b) the amount of water vapor in air compared with the amount the air could hold; (c) the amount of air dissolved in water; (d) the amount of water in tissue.
13. Soil pH is a measure of (a) acid-alkaline condition; (b) humus; (c) water-holding capacity; (d) moisture content.
14. A lichen is (a) an invertebrate; (b) an alga; (c) a fungus; (d) an alga and a fungus.
15. Chemical inhibitors are most likely to (a) speed up the sprouting of seeds; (b) slow down the sprouting of seeds; (c) affect the plant that produces them more than other plants; (d) be found in soil under plants that have many other kinds of plants growing beneath them.

DISCUSSION QUESTIONS

1. Of what use are aquariums and terrariums to persons interested in studying living things?
2. Why is it important to limit the number of animals in a terrarium?
3. How can overgrowth of plants be controlled in an aquarium?
4. What is the function of plants in a "balanced aquarium"?
5. How do the environmental conditions in a bog, a woodland, and a desert terrarium differ? How are they similar?
6. What environmental conditions seem to favor photosynthesis?
7. White light is said to be made up of all colors of light. If this is so, what colors are absorbed by the cellophane when white light passes through red cellophane? When white light passes through green cellophane? When white light passes through a piece of red and green cellophane sandwiched together?
8. What are the major sources of error in measuring the rate of photosynthesis by counting bubbles that come from a piece of *Elodea*?
9. What would you predict about the rate of transpiration in plants adapted to the desert? Why?
10. What environmental factors probably affect succession? Explain.
11. What soil conditions seem to favor plant growth? Explain.
12. What environmental factors seem to influence root growth? What evidence do you have?
13. In what ways is a starfish adapted for life in the sea?
14. What senses do fish seem to possess? What evidence do you have?
15. In what ways are the general growth patterns of plants and animals similar? Different?
16. In what ways is the life cycle of a fruit fly similar to that of a moth?
17. At what stage in the life of a human would you say that the growth rate is most rapid? What evidence do you have?
18. In nature, what factors affect the depth at which seeds are "planted" in the soil?
19. How can it be said that man is dependent upon green plants for his food supply when much of his diet is made up of meat, fish, and eggs?
20. What are the physical factors of the environment? How do such factors affect plants? Animals?
21. Explain how each of the following can be measured:
    a. relative humidity
    b. percentage of water in soil
    c. percentage of humus in soil
    d. soil pH
22. How do the habitats of a water environment differ from those of a land environment?

23. How could you find out if there were any microorganisms in a water community? In a land community? How could you find out how many were present?
24. Describe how plants are preserved by using a plant press.
25. Distinguish between positive and negative interactions among organisms. Give examples of each.
26. In a land community, how are food makers, herbivores, carnivores, parasites, and saprophytes likely to be interrelated?

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Also note the *Guides and Keys* listed at the end of Block I.

BLOCK III

Man and His Environment

Healing arts were practiced in both the old world and the new world long before historical times. These healing arts often were quite primitive, but we must remember that many diseases were shrouded in mystery until the latter part of the past century.

People who lived two centuries ago were well aware that diseases, like the plague and smallpox, appeared as epidemics in which a great many people died. But they did not know what caused these diseases. It had not yet been demonstrated that some diseases are caused by bacteria, and the existence of viruses was not even suspected.

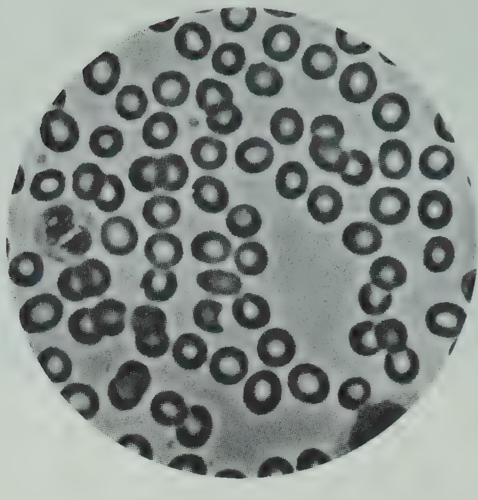
In the later part of the nineteenth century, the world first became aware that certain microorganisms cause diseases. This great breakthrough resulted largely from experiments performed by the French chemist, Louis Pasteur. Pasteur began by studying wines. He found that some wines soured, because bacteria were present in the fruit juices from which the wines were made. He found that heat would kill these bacteria, and thus keep wines from souring.

Pasteur soon learned to raise bacteria in cultures. He found that one species of bacterium caused cholera in chickens, and that another bacterium caused anthrax in sheep. He developed methods of protecting the chickens and sheep against these diseases. But more than anything else, Pasteur showed that bacteria could cause diseases.

Other scientists soon took up the trail, and new discoveries were made. Today we know that many diseases are caused by microorganisms, such as certain bacteria and protozoa. Other diseases are caused by viruses. We know how to defend ourselves against many of these diseases. Some afflictions that once were very common are almost unknown today.

In Block III, you will learn about the human body and how it functions. You will discover how health is maintained, and how diseases are controlled.

CHAPTER 12



The Human Organism

You have learned that many kinds of plants and animals are adapted to the habitats in which they are generally found. Some have ways of protecting themselves against drought. Many of them have adaptations for obtaining food, or adaptations that protect them against potential enemies. Some are especially fitted to live in the water, and some to live on the land. And there are others that are adapted to live both in the water and on the land.

Being a land animal, man has various adaptations that enable him to live in such a habitat. Consider, for example, the problem of moving from place to place. Man's body parts are positioned so that he can resist the pull of gravity and hold himself upright. In this position he is able to walk and to run. For such purposes the bones of the skeleton, and various muscles are of primary importance. In this chapter, you will learn how the skeleton and the muscles of the body work together to produce movement.

THE BODY FRAMEWORK

Man is a vertebrate, and has an internal skeleton consisting of approximately 206 bones. Bone number may vary slightly in different individuals. Included among the bones are those that make up the backbone. The backbone is the "trademark" of a vertebrate.

The human skeleton, like that of any higher animal, serves a number of functions. It gives *form* and *support* to the body. It serves to *protect* a number of internal structures, such as the brain, the heart, and the lungs. It provides places of attachment for a great many muscles. Without the skeleton and these muscles, we would be unable to move about. In addition, the long bones of the body contain ***bone marrow*** in their central cavities. In this bone marrow are special cells which give rise to red and white blood cells.

Cartilage and bone. The skeleton of a very young human being is largely

composed of a substance called ***cartilage*** (*kahr*-ti-lij), which is a good deal softer than bone. Fig. 12–1 is a diagram of a section through one type of cartilage. You can see that this cartilage contains relatively few cells. Between the cells is a great deal of *intercellular substance.* This intercellular substance is material that has been secreted by the cartilage cells.

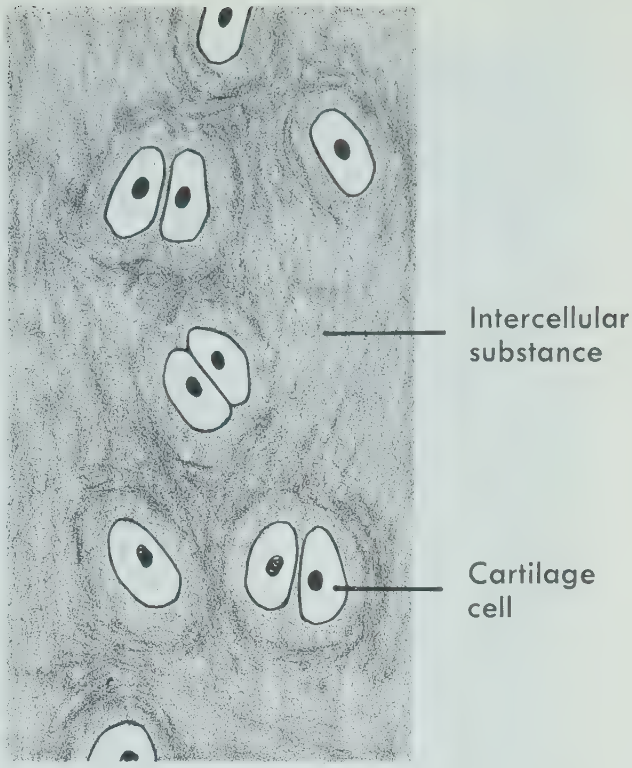
Since there are so few cells in cartilage tissue, you might suppose that a torn cartilage would heal slowly. And indeed, such is the case. The cartilage cells will produce new intercellular substance, but this takes time.

As the human body matures, much of the cartilage in the young skeleton is replaced by bone. Bone tissue also contains relatively few cells and a good deal of intercellular substance. Bone is not nearly as flexible as cartilage. This is because the intercellular substance of bone contains mineral deposits in the form of lime and other hard substances.

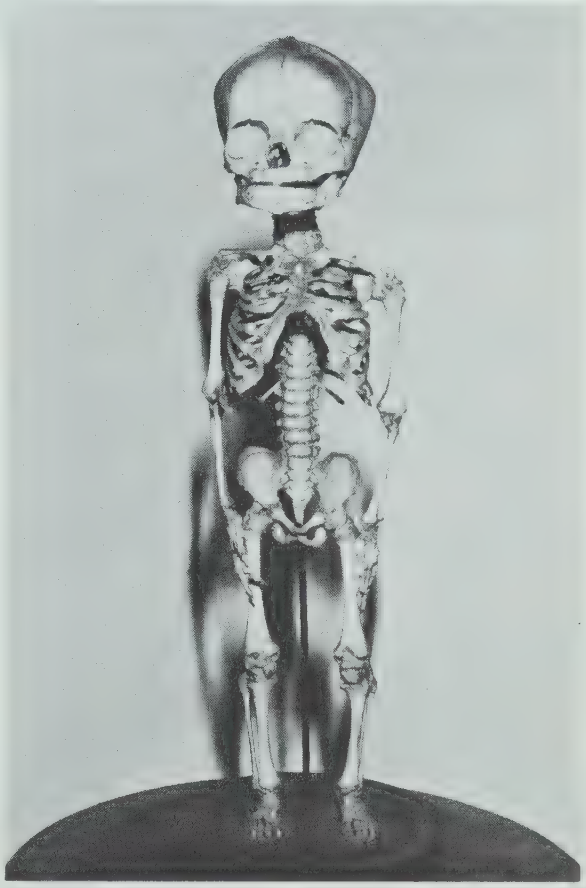
The adult skeleton is largely composed of bone. But you still find cartilage at the ends of some bones. The cartilage of the ears and the tip of the nose remains cartilage throughout life. There is also cartilage in the walls of the passageways leading to the lungs.

Ligaments and tendons. Associated with the bones are ***ligaments*** (*lig*-a-munts) and ***tendons*** (*ten*-duns). Ligaments are bands of tough tissue that hold the ends of certain bones together. Tendons are composed of similar tough tissue at the ends of muscles. Tendons attach the ends of these muscles to other muscles or to bones.

Sprains and dislocations. To sprain an ankle, a thumb, or a wrist is a common experience. Ligaments and tendons of the affected joint have been



12–1. A diagram through a section of cartilage.



12–2. A young child's skeleton is largely composed of cartilage. (*Walter Dawn*)

12–3. X-ray photographs of a simple fracture (left) and a compound fracture (right). (*From the Technical Instructional File of Jerry Harrity*).

stretched too much, and soreness and swelling result. If the sprained area is rested, the pain and swelling usually will go away in time.

A dislocation is more serious. In this case, the bones of a joint have been pulled out of their normal positions. A doctor must bring the bones back to their proper places. Soreness and swelling of the joint may be expected, until the tendons and ligaments have had time to recover from the injury.

Bone fractures. Bones in a young person's body do not contain as much hard mineral matter as they will after age 25. They are, therefore, less brittle than the bones of an older person. But even so, they can be *fractured,* which means that a break has occurred.

A *simple fracture* exists when a bone is cracked, but the parts of the injured bone have remained in place. This type of fracture will usually heal rapidly, if the bone is suitably protected by a cast or some similar device. A more serious type of fracture occurs when the broken ends of a bone are out of place. This is called a displaced fracture. Then a doctor must *set* the broken bone, which means to bring the broken parts back together in their normal position. In a *compound fracture,* part of a broken bone protrudes out through the flesh. The broken bone must, of course, be properly set. And in this type of fracture there is danger of infection, because germs may have gotten into the open wound.

A CARTILAGE SECTION

Your teacher may have a slide of a section through a piece of cartilage. If so, examine the slide carefully, using a microscope or a projector.

CARTILAGE TISSUE Cartilage is, of course, a type of tissue. Locate and examine the intercellular substance of this tissue. In it, you will find small pockets which contain the cartilage cells. Note the number, shape, and general appearance of these cells.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways is a cartilage cell similar to other cells you have observed?
2. If cartilage is torn or otherwise damaged, where does material for the healing process come from?
3. What can you say about the number of cells as compared with the amount of intercellular substance?

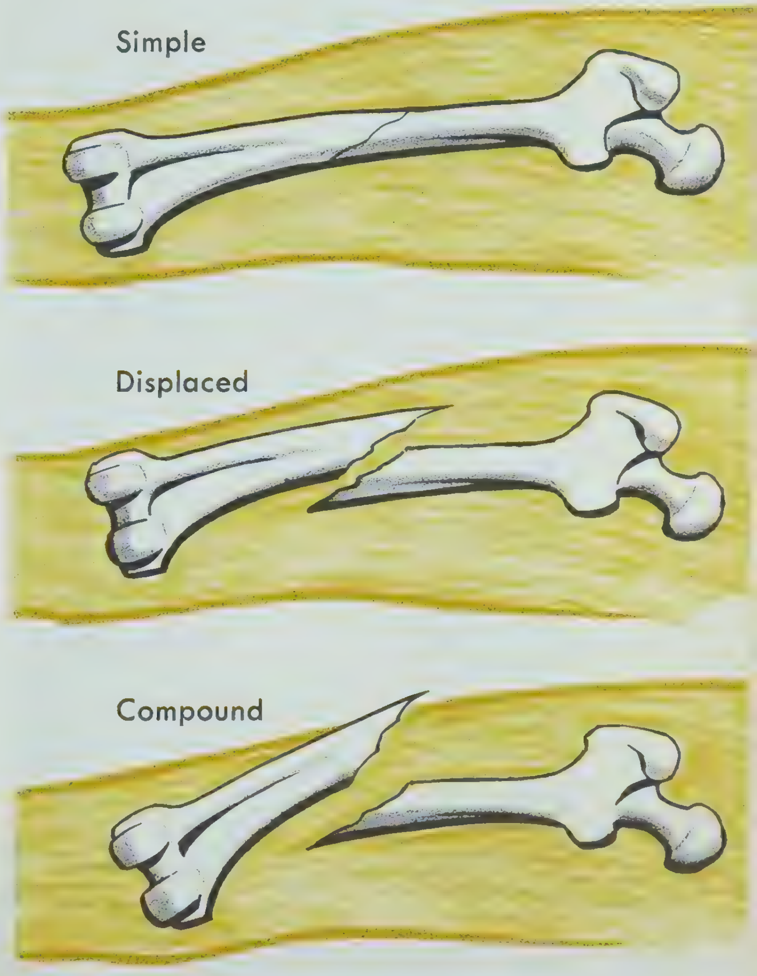
THE HUMAN SKELETON

You probably know some parts of the human skeleton already. No doubt, you can recognize the skull, the backbone, and the arm and leg bones. The parts of the skeleton are shown in Fig. 12–5.

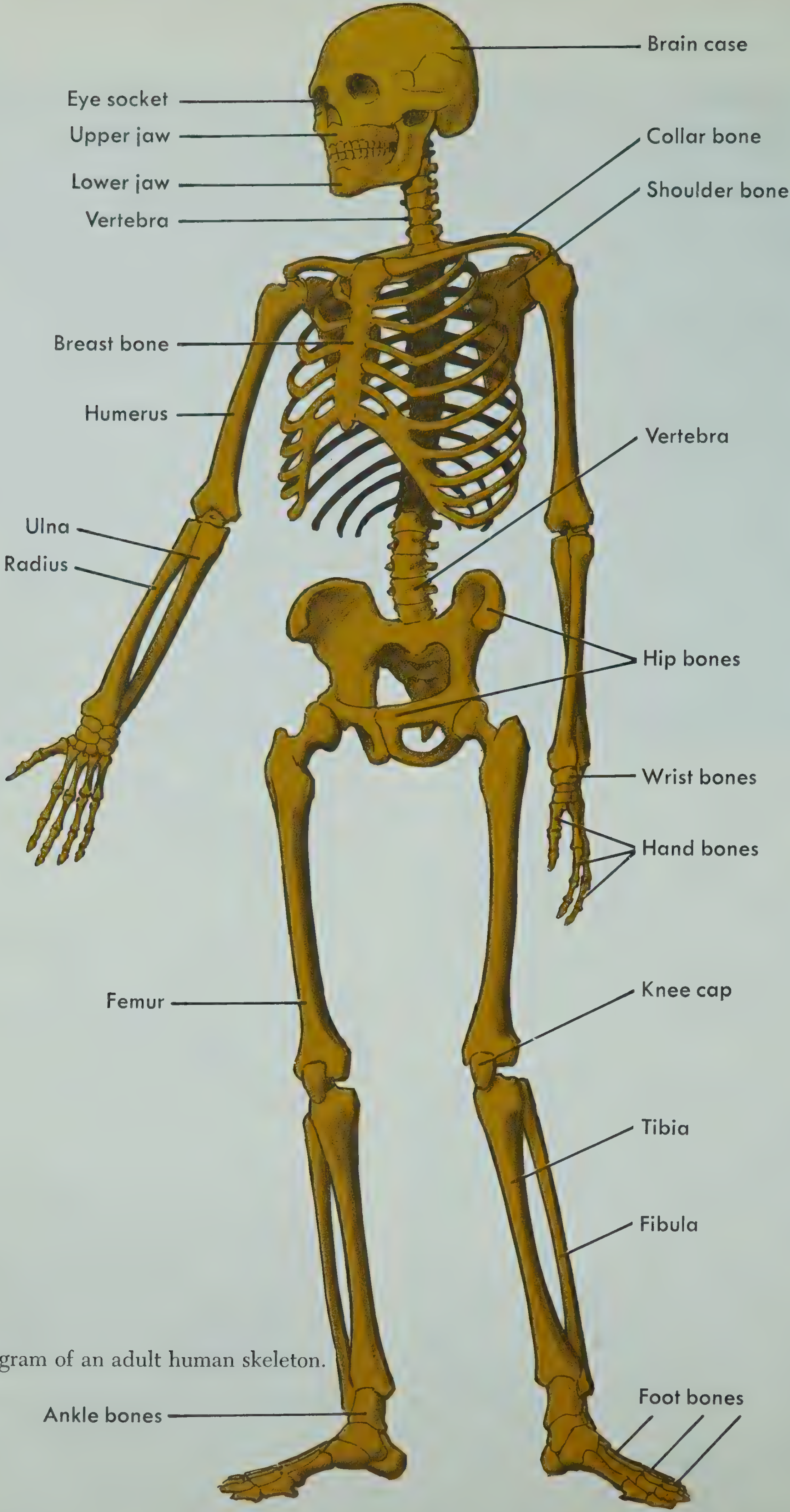
Bones of the head region. The human *skull* consists of a number of bones which are joined together in the adult. Thus, the main portion of the skull forms a rigid protective case around the brain. An opening in the skull serves as a passageway for the *spinal cord*, which is attached to the brain.

The bones of the lower jaw are also joined together in the adult. But the lower jaw is only held to the rest of the skull by ligaments. This arrangement permits opening and closing of the mouth. Both upper and lower jaws contain sockets, in which the teeth are anchored. A full adult set contains 32 teeth.

The backbone. The backbone is made up of parts called ***vertebrae*** (*ver*-tuh-bree). Each vertebra has a cavity through which the spinal cord passes. Some of the vertebrae bear bony spines or processes, to which muscles of the back are attached.



12–4. Three types of bone fractures.



12–5. Diagram of an adult human skeleton.

12–6. If you look carefully at this picture of a human skull, you can see that the skull is made up of many bones joined together. (*Ward's Natural Science Establishment, Inc. Rochester, N.Y.*)

The backbone includes a total of 33 vertebrae. The 12 pairs of ribs are attached to vertebrae of the chest region. The hip bones are joined to five of the vertebrae near the lower end of the backbone. Seven vertebrae in the neck region are attached only to each other and to muscles, which makes it possible to turn the head back and forth.

The first vertebra in the neck is the *atlas.* Bony processes at the base of the skull rest on this vertebra. Just below it is the *axis,* or second neck vertebra. These two bones provide a firm support for the head. At the same time, they make head and neck movements possible.

The arms. There are four bones in the shoulder region: two *collar* bones and two *shoulder* bones, as shown in Fig. 12–5. The inner ends of the collar bones are attached to the breast bone. The two flat shoulder bones are supported by muscles of the back. As you can see, this is not the strongest sort of support. A broken collar bone can render a shoulder and arm largely useless until the injury has healed.

At the point of each shoulder, the outer ends of the collar bone and the shoulder bone come together to form a sort of socket. The upper end of the ***humerus,*** which is the bone of the upper arm, is attached in this socket. Between the elbow and the wrist are two bones: the ***radius*** and the ***ulna*** (*ul*-nuh). There are eight small bones in each wrist, and a number of hand and finger bones.

12–7. X-ray photograph of human vertebrae. (*From the Technical Instructional File of Jerry Harrity*)

The legs. On each side of the body, a thigh bone, known as the ***femur*** (*fee*-mur), fits into a socket formed by the hip bones. The two femurs are the longest bones in the body. At the knee joint a small flat bone forms the knee cap. There are two bones in the lower leg, the ***tibia*** (*tib*-ee-uh) and the ***fibula*** (*fib*-you-luh). The tibia is much larger than the fibula, and it is a part of this bone that is sometimes referred to as the shin. Then there are seven bones in each ankle, and a number of foot and toe bones.

BONE STRUCTURES

Obtain a beef, pork, or lamb leg bone from a meat market. It is called a *long bone.* Bones like the knee cap or breast bone are *flat bones,* and have a somewhat different structure.

A SECTION THROUGH A LONG BONE Examine the bone carefully. It has a thin, fleshy covering of *connective* tissue. Actually, this covering is made up of two *sheaths* or layers. You may be able to locate blood vessels in the outer sheath, and find where they penetrate the bone itself.

Use a meat saw or hacksaw to cut through the middle of the bone. Observe that the outer portion of the bone is hard, due to deposits of mineral compounds. The hollow center is lined with another layer of connective tissue, and is filled with soft bone marrow. In the marrow are fat cells and various other types of cells, including some that produce blood cells.

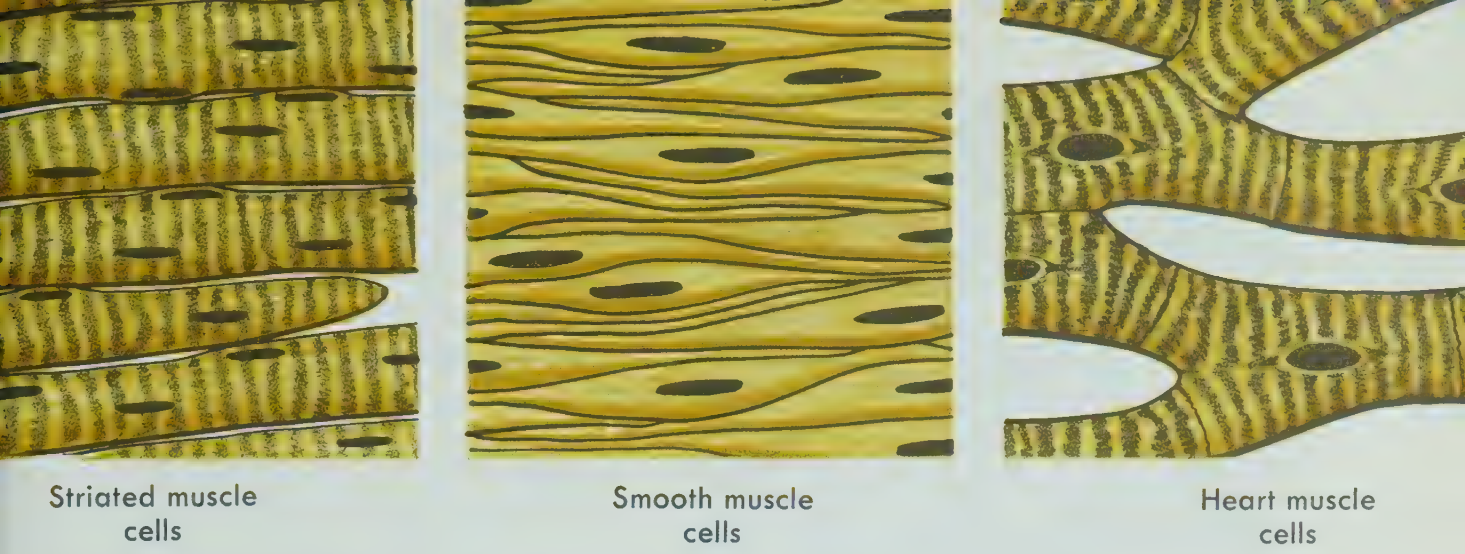
ANALYSIS Prepare answers to the following questions in your notebook:

1. How would you describe a long bone cross section?
2. Why do you think it is necessary for blood vessels to bring blood to and from a bone?
3. Is a bone a living structure, or merely a deposit of mineral compounds? Give reasons for your answer.

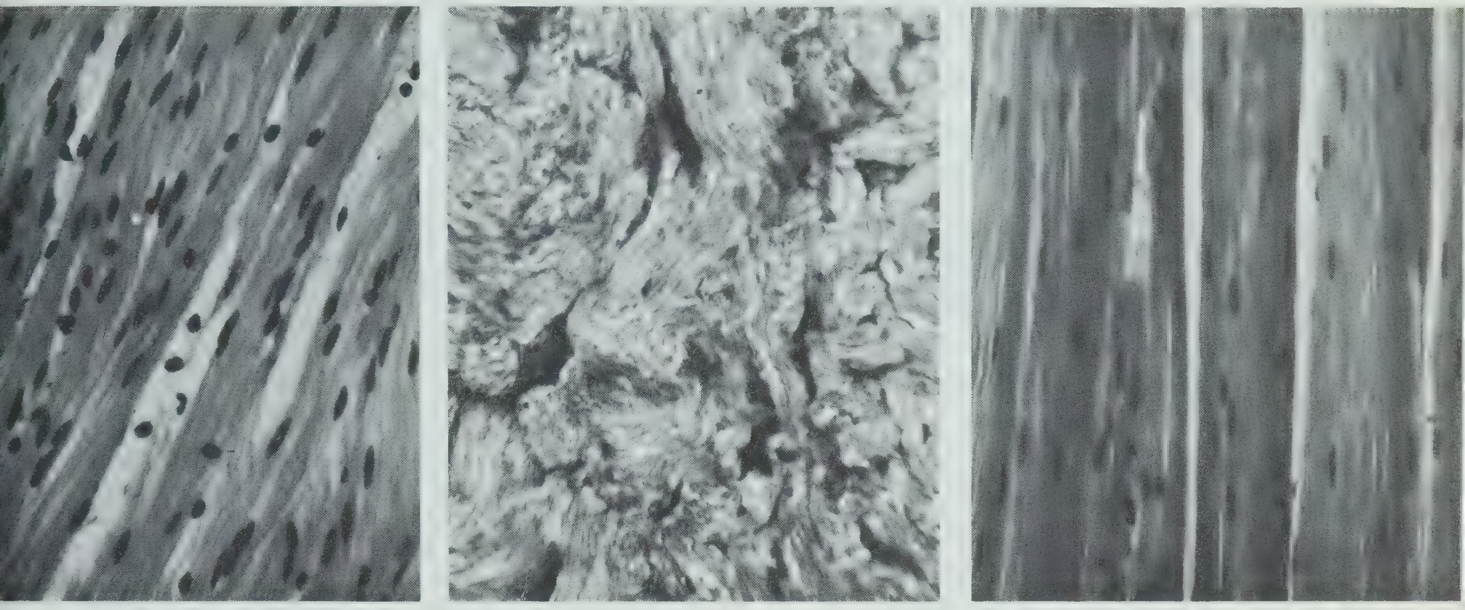
MUSCLE TISSUES

You have learned that many muscles in the human body are attached to bones of the skeleton. At the same time, there are other muscle tissues that are not connected with the skeleton and take no part in producing movements of the body. In fact, there are three general types of human muscle tissue, which are made up of three different kinds of muscle cells. All of these cells are similar in that their main function is to *contract,* or get shorter. When a muscle cell contracts, it exerts a pull, and a pull can produce motion.

The voluntary muscles. Fig. 12–8 shows the three types of muscle cells. ***Striated*** muscle cells are found in the *voluntary muscles* that are generally attached to parts of the skeleton. They are called voluntary, because you can control their actions when you walk, run, or throw a ball. A voluntary muscle is composed of striated muscle cells bound together by connective tissue. At either end of the muscle the connective tissue forms a tendon. Note in Fig. 12–8 that striated muscle cells have many cross striations, and that each cell contains a number of *nuclei.*



12–8. Three types of muscle cells. Left, striated; center, smooth; right, heart muscle.
12–9. Photographs of three types of muscle tissue. Are you able to identify the types of muscle tissue pictured? (*Louis R. Previte*)

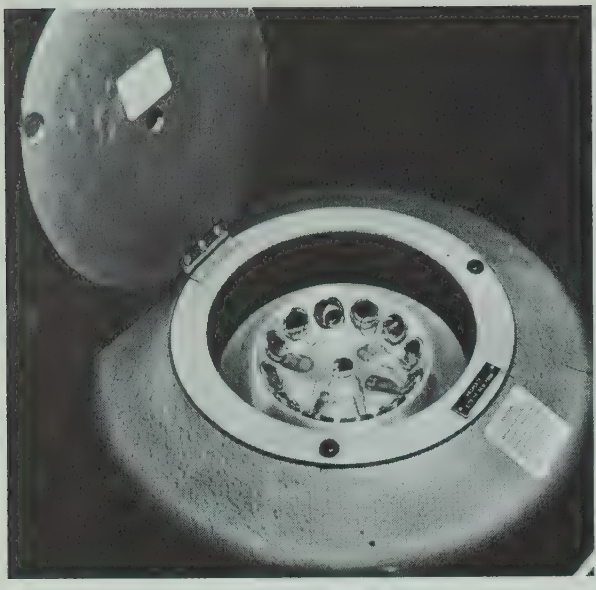


Smooth muscle tissue. The *smooth* muscle cells, shown in Fig. 12–8, have tapered ends, single nuclei, and lack the prominent cross striations. They are the kinds of muscle cells you find in the walls of the internal structures, such as the walls of the stomach, intestines, and blood vessels.

Tissues formed of smooth muscle cells are called *involuntary muscles,* because you cannot *consciously* control their actions. You cannot, for example, cause your stomach to expand or contract at will. Involuntary muscles do not produce the sudden strong contractions that are typical of voluntary muscles. But involuntary muscles can maintain a steady contraction for a long period of time.

Heart muscle. The *heart* muscle cells, shown in Fig. 12–8, are located in the heart wall. These cells have cross striations, and some of them contain more than one nucleus. Their actions are partly automatic and partly under the control of nerves from the brain. But you cannot consciously direct these actions.

Heart muscle contracts to pump blood through a system of blood ves-



12–10. A centrifuge is used in the laboratory to separate the blood cells from the plasma. (*Walter Dawn*)

sels. You may wonder if heart muscles ever gets a chance to rest, because the heart must keep on working throughout life. Actually, the rest periods for heart muscles come between the successive contractions.

MUSCLE FUNCTIONS

Since the action of a muscle cell is limited to contraction, it can only pull in one direction. But voluntary muscles are arranged in opposed groups. One group pulls one way, and another group pulls the other way.

INVESTIGATING MUSCLE ACTIVITY You can demonstrate this kind of action in the muscles of your arm. Hold your right forearm just below the elbow with your left hand. Then make a tight fist with the hand of your right arm. Note that the muscles responsible for forming the fist thicken and feel more solid while the fist is clenched. Now release the fist and extend the fingers of your right hand. Note that the muscles that were contracted are now relaxed, and that a different set of muscles has become contracted.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Where are the muscles responsible for straightening out the fingers?
2. How is it possible for muscles in the forearm to bring about movements of the hand and fingers?
3. What other body movements are due to muscles working in opposed groups? Explain.

THE CIRCULATORY SYSTEM

A single-celled organism, like a bacterial cell, usually can get enough food and oxygen for itself from its surroundings, but in a large complex organism, many cells are far removed from the body surface. These cells cannot obtain food or oxygen, or get rid of wastes by their own efforts. Yet cells must have food and oxygen, and wastes must be removed from the tissues. This is made possible through the action of body fluids and the circulatory system.

Human blood. A person of average size has about six quarts of blood in his body. Over half of this blood is a straw colored liquid known as ***plasma*** (*plaz*-muh). Plasma serves to carry food to cells of the body tissues. It also carries away various wastes that are formed by tissue cells. Hormones, enzymes, salts, and other substances are found in plasma.

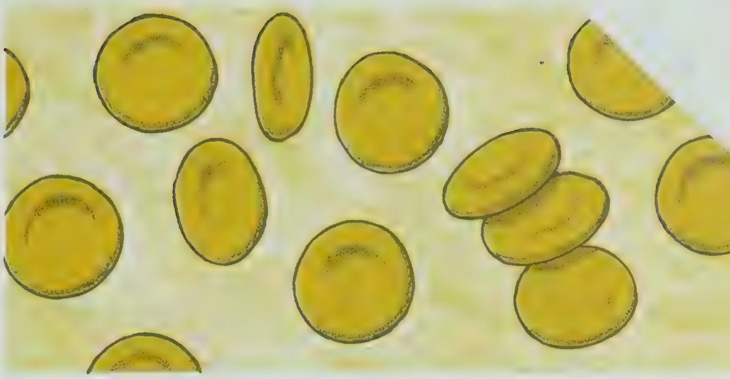
Floating about in the plasma are the red blood cells or ***red corpuscles*** (*kor*-pusl's). Red corpuscles are disc shaped and have no nuclei. They contain a red protein called ***hemoglobin*** (*hee*-moh-glo-bin) which combines readily with oxygen. When red corpuscles pass through the lung tissues they receive oxygen from air in the lung spaces. The red corpuscles then carry this oxygen to cells of the body tissues.

Carbon monoxide (CO) is a gas that is present in the exhaust of automobile engines and in some of the gas used in cooking. Unfortunately, hemoglobin will combine with carbon monoxide much more readily than with oxygen. But carbon monoxide will not support life. When people inhale this gas their red corpuscles soon become loaded with it, and oxygen supplies to tissue cells are greatly reduced. Unconsciousness and death result if too much carbon monoxide is inhaled.

Human blood also contains several types of ***white corpuscles.*** These white corpuscles are not nearly so numerous as the red corpuscles. In blood taken from a vein of a healthy person there may be about one white corpuscle for every 600 red corpuscles.

White corpuscles are able to change shape like an ameba. All white corpuscles contain nuclei. They tend to gather in any tissue that has been damaged or invaded by bacteria. Some of the white corpuscles destroy bacteria and bits of foreign materials.

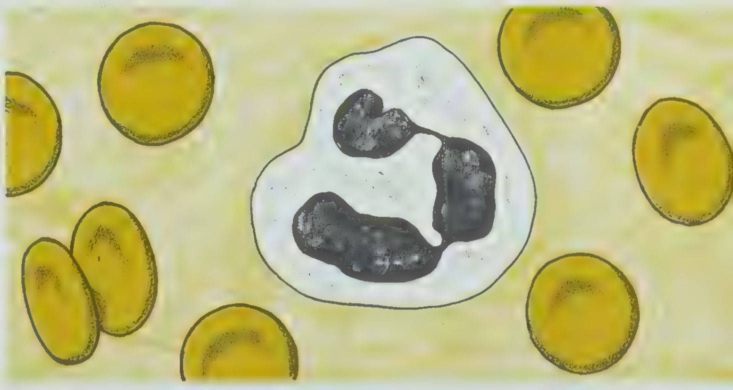
Tissue fluid and lymph. In the tissues of the body, blood vessels branch and rebranch to form networks of tiny vessels called ***capillaries*** (*kap*-ul-arees). These capillaries have very thin walls. White corpuscles can pass through the capillary walls, and so can the more fluid part of the plasma.



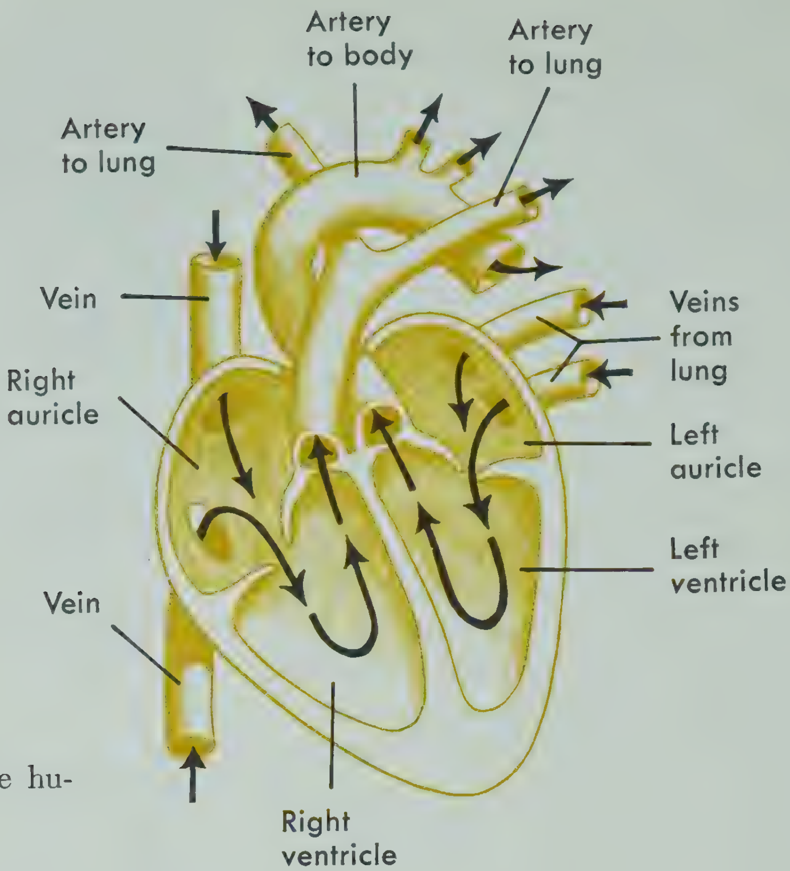
12–11. A diagram of red blood cells.

Plasma that escapes from the capillaries is called *tissue fluid.* Tissue fluid surrounds the cells, bringing needed materials and absorbing waste products. Some of the tissue fluid then moves back into the capillaries, and some of it enters a special group of ***lymph*** (*limf*) ***vessels.*** The fluid in lymph vessels is called *lymph.* Lymph is similar to tissue fluid. Lymph vessels ultimately discharge their lymph into veins. Then the lymph becomes part of the plasma again.

The heart. As may be seen in Fig. 12–13, the human heart has four chambers: a right and left ***auricle*** (*aw*-rih-k'l) and a right and left ***ventricle*** (*ven*-trih-k'l). Blood enters the heart by way



12–12. A diagram of a white corpuscle surrounded by red corpuscles. How does a white corpuscle differ from a red corpuscle? What are the functions of white corpuscles?



12–13. A diagram of the human heart.

of an auricle, and leaves by way of a ventricle. There are *valves* between the auricles and the ventricles, which prevent back flow of the blood. There also are *valves* at the entrances of the two large vessels that carry blood out of the ventricles.

Action of the human heart is so timed that the auricles fill with blood at the same time. The right auricle receives blood returning from all body tissues except the lungs. The left auricle receives the blood that has just been through the lung tissues. Now the auricles *contract,* and blood passes down into the ventricles. After a brief pause, the ventricles *contract* to force the blood out of the heart. Blood from the *right* ventricle goes to the lungs. Blood from the *left* ventricle goes to all other tissues of the body.

The blood vessels. A vessel that carries blood from the heart to other parts of the body is known as an ***artery*** (*ar*-ter-ee). A vessel that carries blood from other parts of the body toward the heart is a ***vein.*** Both arteries and veins have smooth muscles in their walls. There is, however, a good deal more muscle tissue in the wall of an artery than in the wall of a vein.

In the body tissues, the smaller arteries branch to form capillaries. These capillaries are continuous with other capillaries that come together and form veins. So in a tissue there is a *capillary network* made up of many tiny capillaries.

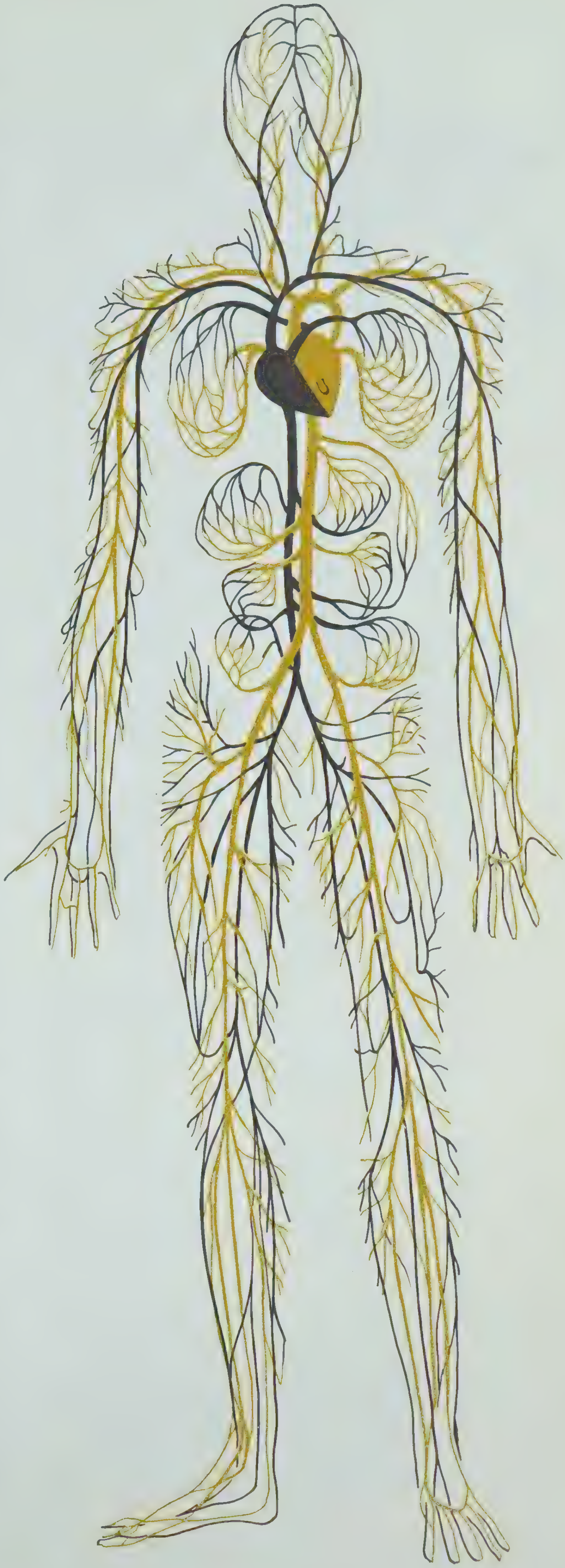
Fig. 12–14 is a diagram which shows the main arteries and veins of the human body. Note that two large arteries and their branches carry blood to the head region. A large artery and its branches supplies blood to each arm and each leg. Other arteries convey blood to the organs that occupy the

body cavity. Meanwhile, a system of veins, that parallels the system of arteries, brings the blood back from other parts of the body to the heart. Veins, that bring blood back toward the heart, have valves that prevent back flow. The return of this blood to the heart is speeded up by body movements that put pressure on certain veins.

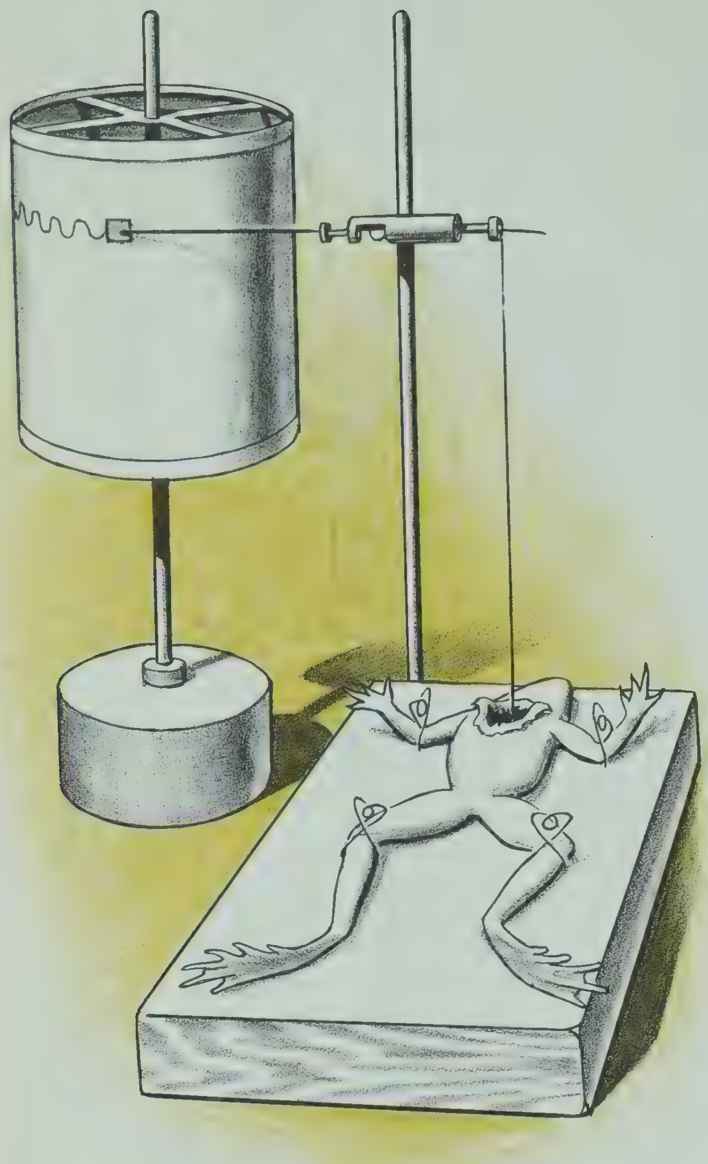
CIRCULATION IN A FISH TAIL

If you have a small goldfish, or other small fish, in your aquarium, you can easily observe blood circulation. First, wet a small sheet of cotton thoroughly. Wrap the wet cotton around the head portion of the fish; this will keep its gills moist and thus prevent death. Use a rubber band to attach the fish to a blank microscope slide. Spread out the fish tail on the surface of the slide. Now you are ready to observe your specimen with the aid of a microscope or projector.

AN OBSERVATION OF BLOOD FLOW Focus on the end of the fish tail. Probably the first things you will notice are some jointed rodlike parts; these are small bones that support the tail. Look between these bones, and you will see blood moving through a variety of small vessels. You may even see thousands of corpuscles as they move along. Note that the blood is moving faster in some vessels than in others.



12–14. A diagram of the main arteries and veins of the human body.



12–15. In the laboratory, a kymograph is used to record the heartbeat of experimental animals.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How can you tell whether a blood vessel in the fish tail is an artery or a vein?
2. Are the red corpuscles you see in the fish tail shaped like human red corpuscles? Explain.
3. Does the blood seem to flow at the same rate in all vessels? Explain.

FUNCTIONS OF THE CIRCULATORY SYSTEM

Circulation is involved in carrying out a number of very important functions. Some of these functions have been mentioned previously, but now let us consider them in greater detail.

Absorption and transportation of food. You will study food and digestion in detail in Chapter 13. For the moment, all you need to know is that most food is digested and absorbed in the region of the small intestine, which is the portion of the digestive canal that food passes through after it leaves the stomach.

Digested food enters the circulation through both capillaries and lymph vessels in the wall of the small intestine. In either case, the food molecules reach the blood plasma, and are moved to cells of the body through the medium of the tissue fluids that pass through the capillary walls.

Transportation of oxygen. Red corpuscles are primarily oxygen carriers, but they do take some carbon dioxide away from the tissues. Their hemoglobin combines with oxygen to form an oxygen-rich compound, and this compound supplies oxygen to the body tissues. There are about 20 trillion red corpuscles in the human system, and each of them lives only from three to four months. However, red corpuscles are constantly being produced by special cells of the bone marrow.

When the number of red corpuscles falls below the normal level, or the amount of hemoglobin in the blood is insufficient, the condition known as ***anemia*** (*uh*-nee-mee-uh) results. Anemia can be caused by accidental loss of blood, lack of iron, infection, and some types of poisoning.

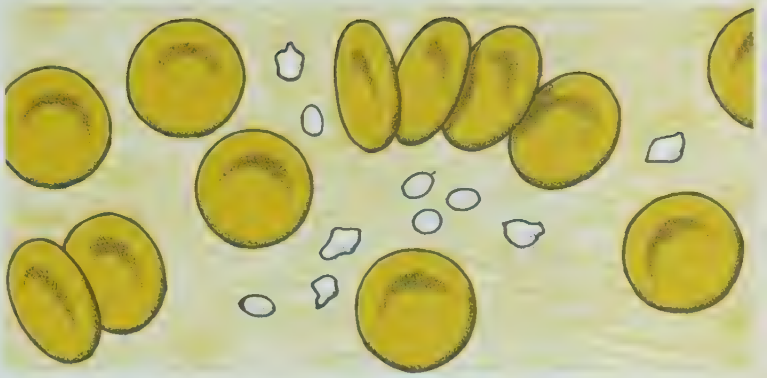
It is also possible to have too many red corpuscles in the blood. This is a dangerous condition that is due to the fact that bone marrow cells are forming red corpuscles faster than they should.

Waste removal. One common waste product of cells is the gas carbon dioxide. Other wastes result from the breakdown of protein compounds. The plasma removes all of the protein wastes and most of the carbon dioxide wastes from the tissues. Ultimately, these wastes leave the body by way of the lungs and the kidneys.

Blood clotting. Clotting is a normal function of blood. If blood did not clot, you would lose large amounts whenever you injured yourself.

Plasma contains some very minute disc-shaped bodies, known as ***platelets*** (*plait*-luts). When these platelets come in contact with a rough surface, produced by a cut or similar injury, they break down and release certain chemical substances. These substances react with other substances in the blood plasma. After a series of chemical changes, a protein dissolved in the plasma becomes a mass of fibers. The protein fibers, together with blood cells and platelets, form a *clot.* The clot prevents further loss of blood.

Heat regulation and fluid control. Whenever cells and especially muscle cells do work, one product of their activity is likely to be heat. Normal body temperature averages 98.6°F, and if heat were allowed to accumulate in the tissues, the condition known as *fever* would develop. This does not ordinarily happen, because excess heat is lost from the body by way of the blood, the lung tissues, and the skin. Actually, most of the excess heat leaves the human body by passing from small blood vessels in the skin to the air. The evaporation of perspiration also cools the skin in warm weather.



12–16. A diagram of platelets surrounded by red blood cells. Notice the difference in size.

Control of the amount of fluid in the tissues is of very great importance. In this case, the blood plasma is the main distributor and collector of water. The tissue fluids, of course, are also involved in the process. Normally, plasma is about 92 percent water. Excess water is removed from the plasma as the blood passes through the kidneys.

Defense against infections. The blood plays a significant role in the body's defense against certain microorganisms. You have read that some of the white corpuscles destroy bacteria. But another line of defense is also actively at work.

In the plasma are compounds which dissolve various microorganisms. There also are compounds which neutralize poisons released by other microorganisms. These defending plasma compounds are known as ***antibodies*** (*antuh*-bodies).

Other blood functions. In addition to all of the other functions in which the blood has some part, the plasma serves as a carrier for hormones, en-

12–17. Of the native Australian Aborgines, who have been tested, not one has been observed to have blood of the *B* type. (*Australian News and Information Bureau*)

zymes, and other substances essential to normal cell life.

BLOOD VARIATIONS

Like anything else in the human body, the blood varies from one person to another in its chemical composition and structure. You probably know that when blood is given from one person to another person, tests must be made to assure that the donated blood is of the right type.

Blood types. The type of blood you happen to have is determined by heredity. There are four human blood types known as *A*, *B*, *AB*, and *O*. People who have *AB* blood make up only about 3 percent of the North American population. About 10 percent of this population have the *B* type of blood. The rest are about equally divided among people who have the *O* and the *A* type. In other areas of the world, however, the story is somewhat different. For instance, all native Indians of Peru, who have been tested, have blood of the *O* type.

Other variations. There are other variable factors in human blood that you will learn about in your later studies. There are also cases in which people lack certain blood substances, and have a type of blood that will not clot normally. This condition is known as hemophilia (*hee*-moh-*feel*-ee-uh). Some individuals have more than a normal quota of red corpuscles or white corpuscles. In other people, the red corpuscles or white corpuscles may be below normal levels.

BLOOD PRESSURE

As the blood leaves the left ventricle of the heart, it is under considerable pressure. Farther along in the arteries and branch arteries, the pressure may drop somewhat, but it is still fairly high. Then in the *capillary* networks pressure drops to a low level. This is because the capillary networks are "a wide place in the road." To be sure, each capillary is very small, but there are so many capillaries that their blood-carrying capacity *exceeds* that of the arteries. The blood reaches the veins under low pressure, but this pressure builds up again as the blood moves back toward the heart. Pressure, however, is never as high in the veins as in the arteries.

High blood pressure. As a person grows older, small arteries in the tissues tend to get less elastic. There is less space in them for the blood to flow. The heart must work harder to pump blood out into the capillaries. The heart usually will respond to this challenge up to a point. Beyond this point, a heart failure may occur. A heart failure simply means that the heart muscle cannot contract forcibly enough to insure efficient circulation.

Hardening of the arteries. Hardening of artery walls is associated with high blood pressure. The walls of the arteries become less elastic, and calcium compounds may be deposited in them. A hardened artery is likely to be brittle, and there is always danger that it will break open or rupture.

Hardening of arteries is speeded up by certain types of poisoning and infections, and by severe physical or mental effort over a long period. The condition is related to many cases of kidney and heart diseases, which together, are the main causes of death in the modern world.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. antibody	Chamber from which blood leaves the heart.
2. auricle	Chemical that destroys microorganisms or neutralizes their poisons.
3. hemoglobin	Substance that is found in the cavities of long bones.
4. ligament	Type of muscle tissue found in the stomach wall.
5. marrow	Tough tissue that binds the ends of bones together.
6. plasma	Liquid part of the blood.
7. smooth	Red protein found in certain blood cells.
8. striated	Tissue that binds muscle to bone.
9. tendon	Voluntary muscle tissue.
10. ventricle	Chamber through which blood enters the heart.

B

1. anemia	Vessel through which blood enters the heart.
2. artery	Thinnest walled type of blood vessel.
3. capillary	Condition due to lack of hemoglobin.
4. femur	Plasma that has escaped from a capillary.
5. humerus	Bacteria destroying cell.
6. red corpuscle	Vessel through which blood leaves the heart.
7. tissue fluid	A single part of the backbone.
8. vein	Upper arm bone.
9. vertebra	Thigh bone.
10. white corpuscle	Oxygen-carrying cell.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The presence of a skeleton is the "trademark" of a vertebrate.
2. Red blood cells are formed in the bone marrow.
3. Cartilage is made up of cells that are tightly packed together.
4. There is no cartilage present in the adult skeleton.
5. In a compound fracture, a bone end breaks through the flesh.
6. The human skull consists of a single bone that surrounds the brain.
7. A full set of adult teeth consists of 32 teeth.
8. The individual parts of the backbone are called "spines."
9. Because bones are made up of nonliving mineral substance, they do not have a blood supply.
10. Voluntary muscles are striated muscles.
11. The muscle cells in the stomach and intestine walls have tapered ends and a single nucleus.
12. Some muscle cells pull by getting shorter, while others push by getting longer.
13. Voluntary muscles are arranged in groups, so that if one group causes movement in a certain direction, another group causes movement in the opposite direction.
14. In a large complex body, each cell must maintain a proper environment for itself.
15. Food, hormones, enzymes, and salts are carried in blood plasma.
16. Red blood cells contain an oxygen-carrying protein called hemoglobin.

17. Carbon monoxide gas causes death by destroying blood cells.
18. White blood cells are able to change shape.
19. Plasma that leaves the capillaries and surrounds body cells is lymph.
20. The human heart is timed so that the auricles and the ventricles fill with blood at the same time.
21. A blood vessel that carries blood from the heart to the lungs would be called an artery.
22. Most food is digested and absorbed while it is in the stomach.
23. A person who has too few red blood cells is said to have anemia.
24. A blood clot is made up of protein fibers, blood cells, and platelets.
25. Antibodies in the blood serve to remove excess tissue fluid.
26. Hardened arteries are more likely to break or rupture than are normal vessels.

DISCUSSION QUESTIONS

1. In what ways are the bones and muscles of man adapted to life on land?
2. How do bones function as protective structures? What other functions are served by bones? Give examples.
3. Distinguish between bone and cartilage.
4. What is a sprain? A dislocation?
5. In what ways are some fractures more serious than others?
6. How do neck vertebrae differ from those of the chest?
7. Explain why a broken collar bone may make an arm useless.
8. In what ways are arm and leg bone structures similar? Different?
9. All muscles pull rather than push. How, then, is it possible for you to push a table or a chair across a room?
10. How does heart muscle tissue resemble voluntary muscle tissue? Smooth muscle tissue?
11. Explain the advantage of having muscles arranged in opposing groups.
12. What is the function of plasma?
13. Distinguish between tissue fluid and lymph.
14. Describe how oxygen gets from the lungs to the body cells.
15. Explain how carbon monoxide gas causes unconsciousness or death.
16. In what ways is the blood adapted to resist the invasion of microorganisms?
17. Describe the pattern of blood flow through the heart.
18. What is meant by a "capillary network"?
19. Distinguish between an artery and a vein.
20. How does blood function in the removal of body wastes?
21. Explain how a blood clot forms.

22. What body functions tend to produce heat? Remove heat?
23. What is meant by "blood type"?
24. Explain how blood pressure changes from one kind of blood vessel to another.
25. Why is high blood pressure a serious condition? Why is hardening of the arteries a serious condition?

THINGS TO DO

1. Observe actual specimens or diagrams of skeletons of a fish, an amphibian, a reptile, a bird, and a mammal. Compare the ways in which they are similar and different. Describe the ways in which the skeletons illustrate adaptations to different environments.
2. Carefully observe an earthworm moving over the surface of some soil. Try to explain how the muscles might be arranged in the earthworm's body to enable it to move this way. Remember that an earthworm has no skeleton and that muscles can only pull. (Hint: Pick up the worm and run your fingers gently along its body surface. Also notice the difference between the diameter of the body when it is contracted and when it is expanded.)
3. Using hinged pieces of wood to represent bones and heavy rubber bands to represent muscles, build a model of the human arm or leg. With your model, illustrate how muscles work in groups which oppose one another.
4. Prepare a bulletin board display to illustrate the way in which blood flows through the chambers of the heart. Include the lungs and major blood vessels associated with the heart. Use red construction paper to represent those parts that carry blood with high oxygen content, and blue paper for those parts carrying blood with low oxygen content.
5. Using reference books as a source of information, write a report on one of the following topics:
   - The life of a blood cell
   - Blood defenses against disease
   - Heart and blood vessel diseases
   - Blood clotting mechanisms
   - Blood types

   Report your findings to the class.

READING FURTHER

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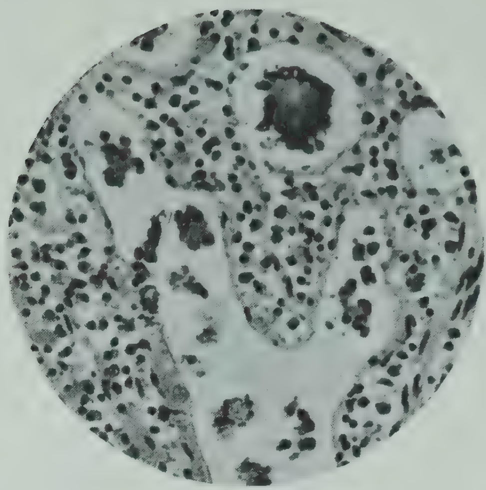
CHAPTER 13



Food for Man

Every living thing depends upon its environment for energy and the materials needed for growth and repair. Green plants get energy from sunlight and needed chemicals from the air and the soil. Nongreen plants and all of the animals get energy and many necessary chemicals from the bodies of other organisms.

Similarly, the human body requires materials from its environment. The food you eat includes a variety of substances that come from many plants and animals. Such materials provide you with chemical bond energy and chemicals with which to build your body. However, many food substances are made up of complex molecules that must be broken down or *digested* before they can be used. Only in simpler form can such materials be absorbed by the blood or lymph and be carried to cells of the body tissues. In the next section, digestion will be discussed in some detail. As you read this section, refer frequently to the diagram of the digestive system, Fig. 13–1 on page 309.

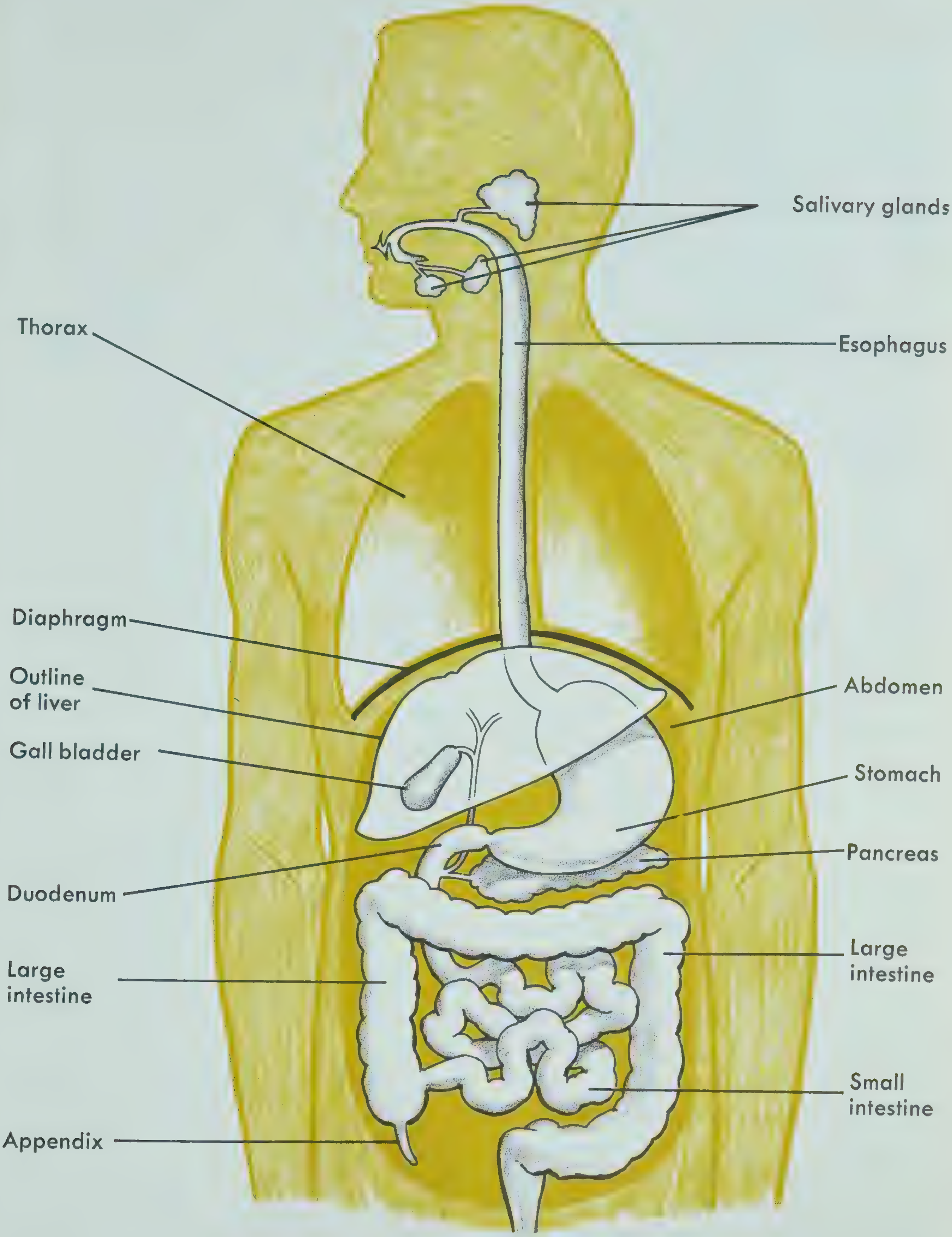
THE DIGESTIVE SYSTEM

Man's digestive system includes a number of organs and some glands that are associated with these organs. The organs and related structures form a digestive canal that is 25 to 30 feet in length.

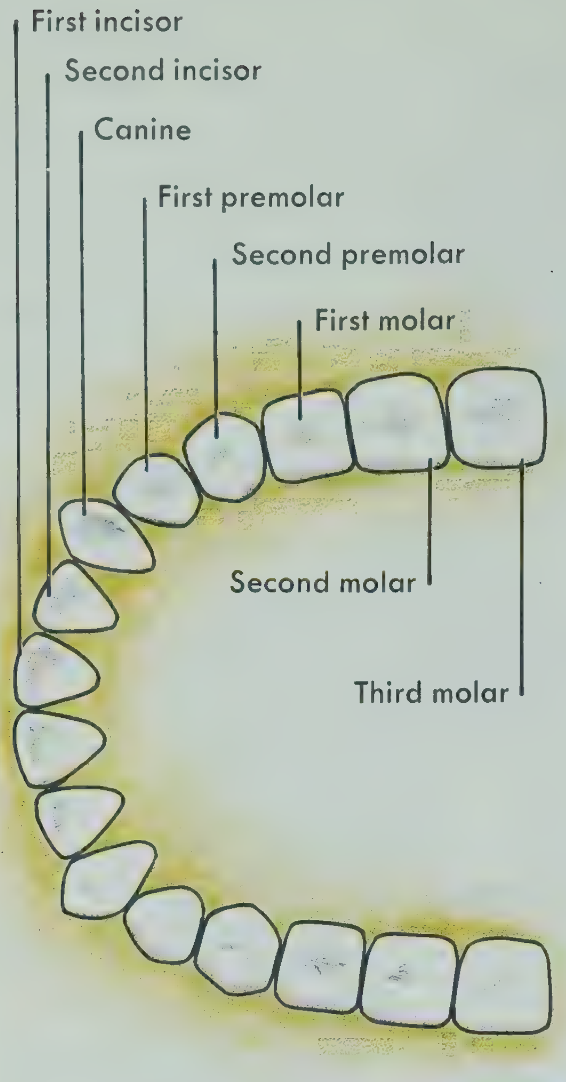
The mouth cavity. Lying between the upper and lower jaws, the mouth cavity receives food, and holds it until it has been chewed and mixed with ***saliva.*** Three glands on each side of the head, as shown in Fig. 13–1, produce the saliva, which passes through ducts to the mouth cavity.

In some animals, saliva contains no digestive enzymes, and simply acts as an aid in swallowing. But human saliva has an enzyme called ***ptyalin*** (*tie*-al-in) which changes starch into sugars. Ptyalin is thoroughly mixed with the food in the mouth and continues to act on the food in the stomach for some time.

The teeth break food into small pieces, which are easier for the diges-



13–1. Diagram of the digestive system.



13–2. An adult set of teeth.

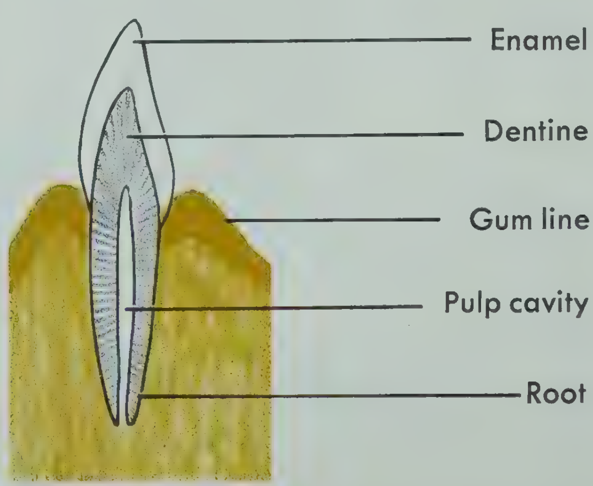
tive system to process. Two sets of teeth are developed in a lifetime, the 20 milk teeth of an infant, and the 32 teeth of an adult. As shown in Fig. 13–2, man has *4 incisors, 2 canines, 4 premolars,* and *6 molars* in each jaw. The last molar on each side is the so-called "wisdom tooth," which generally develops long after the rest of the teeth have appeared.

The incisors and canines serve to bite off portions of food. The premolars and molars have broad upper surfaces and do most of the work of chewing. The tongue acts to keep food between the teeth in the chewing process, and is an aid in swallowing. Nerve endings on the tongue enable you to taste the substances that enter your mouth. As a result, you may be warned of harmful materials that otherwise might be swallowed. Of course, your sense of taste also enables you to enjoy the different flavors of foods.

Fig. 13–3 shows a section through a human tooth. Above the gum line the bulk of the tooth is composed of ***dentine*** (*den*-teen). Covering the dentine is a much harder layer of ***enamel.*** The root of the tooth contains a ***pulp cavity,*** through which nerves and blood vessels reach the interior of the tooth.

Cavities in teeth form when the protective outer layer of enamel is cracked or decomposed by bacteria. Being much softer, the dentine tends to decay rapidly in some cases. Such decay is speeded up by the presence of microorganisms. This is why cavities should be cleaned out and filled as promptly as possible. When decay approaches the pulp cavity, the situation becomes serious.

In man, the ***pharynx*** (*fahr*-incks) is just the back of the mouth cavity. It has muscular walls that contract to force food on its way. The pharynx also contains the opening through which air passes in going to and from the lungs.



13–3. A section through a human tooth.

Sometimes foods or liquids are accidentally drawn into the air passages. Then we cough until they are forced out.

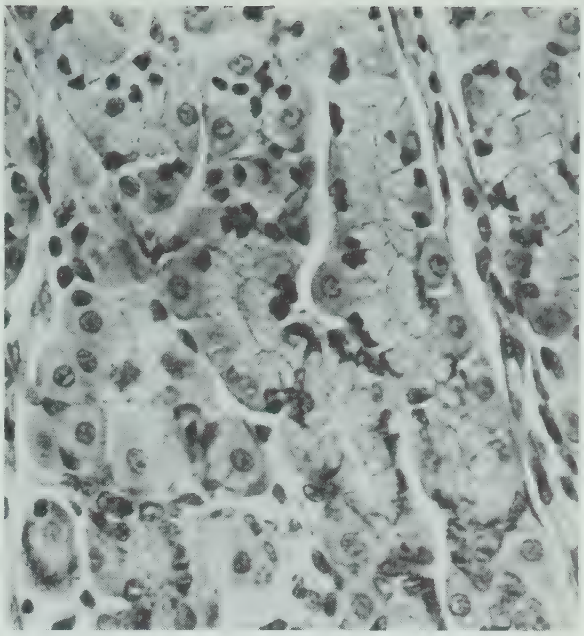
The esophagus. The ***esophagus*** (uh-*sof*-uh-gus) is a muscular tube, which conveys food from the pharynx to the stomach. Note in Fig. 13–1 that the esophagus passes through the ***diaphragm*** (*dia*-fram) before it reaches the stomach. This diaphragm is a layer of muscle and connective tissue that separates the body cavity into two parts: the thorax above, and the abdomen below.

When food enters the esophagus, its muscular wall contracts behind the food mass. Then a traveling wave of contraction forces the food mass down the esophagus to the stomach.

The stomach. The stomach lies on the upper left side of the abdomen. Its wall contains connective tissue, muscle tissue, blood vessels, nerve endings, and a lining of ***gland cells.*** The gland cells are grouped to form the stomach glands, which produce a secretion called ***gastric*** (*gas*-trik) ***juice.***

Muscle contraction in the wall of the stomach gradually forces food along its way. Meanwhile, the food is acted upon by ptyalin, and also by enzymes of the gastric juice. These enzymes in gastric juice begin the digestion of protein foods.

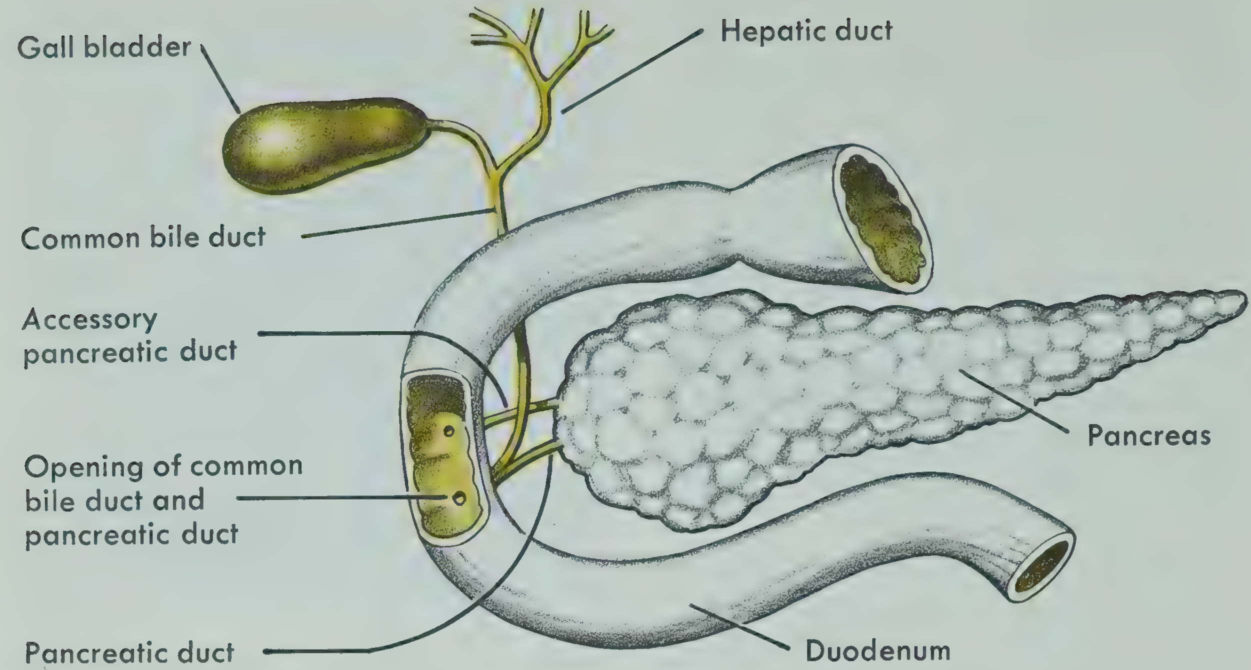
As food passes from one end of the stomach to the other, it becomes more thoroughly mixed with gastric juice, and also becomes more liquid. When it reaches the end of the stomach, it must pass through a valve to enter the small intestine. This valve consists of circular muscle bands in the wall of the digestive canal. The muscles relax at regular intervals, and each time they do so, the valve opens and a portion of food passes into the small intestine.



13–4. The gland cells that line the stomach produce a secretion of gastric juices. (*Walter Dawn*)

The small intestine. The first loop of the small intestine, as shown in Fig. 13–1, is called the ***duodenum*** (duo-*deh*-num). The rest of the small intestine lies in the mid-portion of the abdomen. Waves of muscle contractions push food along the small intestine at the rate of about an inch per minute. Most of the chemical changes of digestion take place in the small intestine. Foods are broken down into simple compounds that are soluble in water.

The ***pancreas*** (*pan*-kree-us) is a light-colored, flattened gland that lies in the loop formed by the duodenum, as shown in Fig. 13–5. It has a key role in digestion, because it secretes enzymes which act upon carbohydrates, proteins, and fats. These enzymes are delivered to the duodenum through a ***pancreatic duct,*** and in some people through an accessory pancreatic duct as well. This variation in the number of pancreatic ducts is another example of the many ways in which people differ from one another.



13–5. Diagram showing the duodenum and pancreas.

The digestive fluid of the pancreas contains a carbohydrate-splitting enzyme, a fat-splitting enzyme, and three protein-splitting enzymes. The process of breaking down fats may be speeded up by the presence of bile from the liver, but bile contains no digestive enzymes. The action of all the pancreatic enzymes upon foods takes place, of course, in the small intestine.

Meanwhile, gland cells in the wall of the small intestine secrete another digestive fluid. This intestinal fluid contains enzymes that act upon carbohydrates and complete the digestion of proteins, but they do not act upon fats.

Absorption of digested food. Alcohol and some spices can be absorbed by blood vessels in the wall of the stomach. The main absorption center, however, is the small intestine. When digestion is completed, proteins have been broken down into *amino acids,* carbohydrates into *simple sugars,* and fats into *glycerol* and *fatty acids.*

The end-products of digestion are absorbed in the wall of the small intestine by blood and lymph vessels in the ***villi*** (*vill*-eye). The villi are great numbers of fingerlike projections on the inner surface of the intestine. Amino acids and simple sugars enter the blood vessels of the villi, while the end-products of fat digestion are absorbed in part by lymph vessels and in part by blood vessels. Figure 13–6 shows both a diagram and a photograph of villi.

Some of the simple sugar absorbed in this manner is glucose. But two other simple sugars are present, and these are converted into glucose by cells of the liver. Liver cells are also able to change glucose into ***glycogen*** (*gli*-koh-gen), a starchlike substance which is stored in liver cells. Glycogen can be changed back into glucose whenever more glucose is needed.

Glucose is delivered to cells of the body by the blood, and is the main source of energy for these cells. Some cells in the body tissues can convert

excess glucose into fat, which is then stored for future use. Some muscle cells can also convert glucose into glycogen for storage purposes.

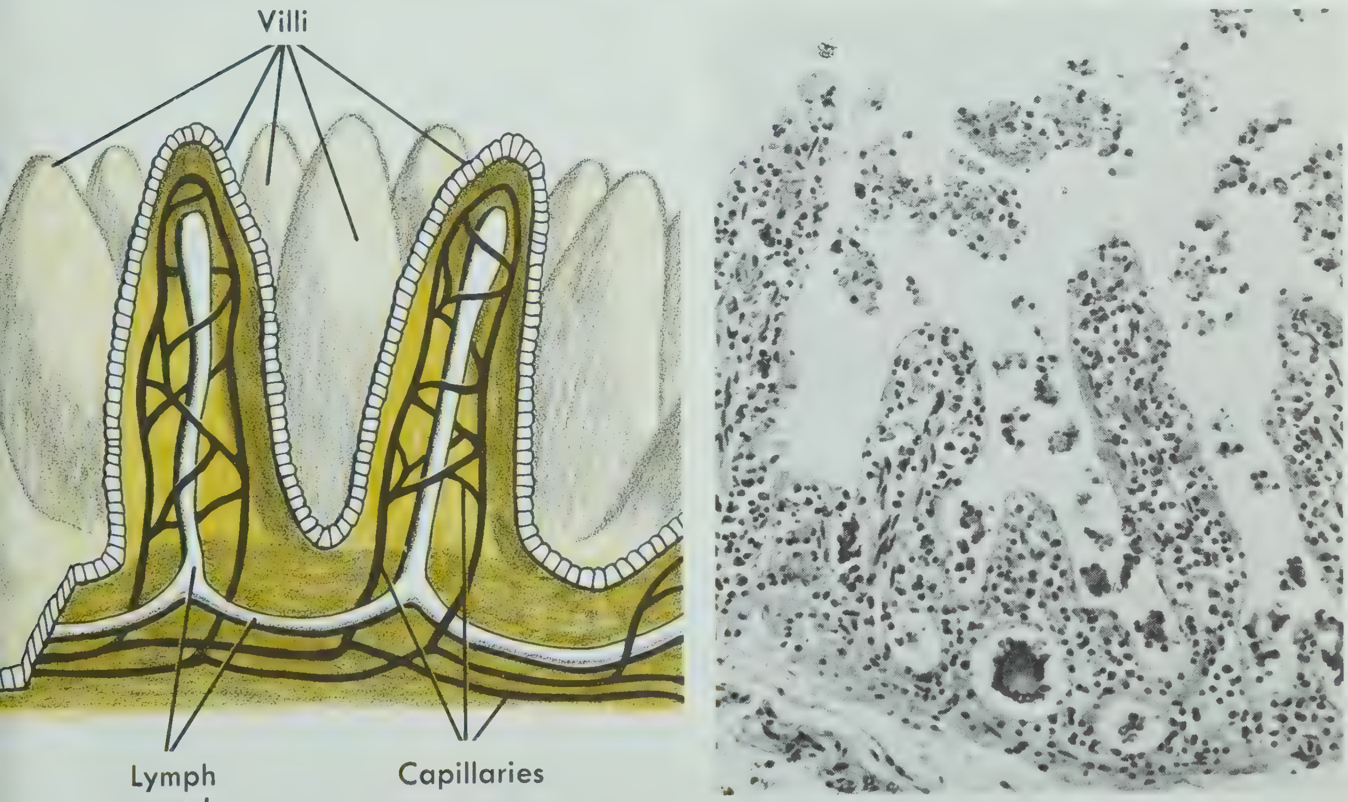
The end-products of fat digestion are processed by liver cells too. After this has been done, the fats can be oxidized by body cells to provide another source of energy. They can also be stored by cells of fat tissues.

The amino acids that result from protein digestion are used primarily to build and repair the protoplasm of body cells. If the amino acids are present in excess, they can be altered by liver cells so that other cells can oxidize them, or they can be converted into glycogen and fat for storage.

The large intestine. As may be seen in Fig. 13–1, the large intestine has its origin at the lower right side of the abdomen. The ***appendix*** is located near this point. From its placé of origin, the large intestine passes upward on the right side of the abdomen, crosses the abdomen just below the level of the stomach, and then extends downward and backward to the anal opening.

In some grass-eating animals, the large intestine is an important digestive center. In man, however, absorption in this region is more or less limited to water, which is taken in by blood vessels of the intestinal wall. This recovery of water is an important adaptation for life on land. The remaining solid material is composed mostly of undigested food and bacteria. These materials are eliminated from the body.

When a person has an attack of appendicitis, his appendix has become ***infected*** (in-*fek*-ted). Various bacteria normally live in the intestines. However, most of them do no harm to the body, and some of them may even be useful. But now and then, some danger-



13–6. Left, a diagram of the villi of the small intestine; right, a photograph of villi magnified 300 times. (*Right, Robert F. Waldeck*)

ous bacteria get into the intestine. Some of them may begin to grow and multiply in the appendix. Then the appendix is infected.

An infected appendix becomes swollen and sore. There is always danger that it may rupture, and that infection will spread through the cavity of the abdomen.

INVESTIGATING ENZYME ACTION

A stomach enzyme, pepsin, can be obtained from biological supply houses in powdered form. To observe its action upon proteins, proceed as follows.

THE ACTION OF PEPSIN UPON EGG PROTEIN Obtain some boiled egg white, which is largely protein, and place a very thin slice in each of five test tubes. Add the following to the contents of the test tubes:

Test tube 1. An inch of water
Test tube 2. An inch of 5 percent solution of pepsin in water
Test tube 3. An inch of water and 7 drops of dilute hydrochloric acid
Test tube 4. An inch of 5 percent solution of pepsin in water and 7 drops of dilute hydrochloric acid
Test tube 5. An inch of 5 percent solution of pepsin in water, that has been boiled for a minute or two, and 7 drops of dilute hydrochloric acid

Keep all of the test tubes in a water bath at about 98°F for an hour or longer. Record any changes in the appearance of the egg white in the various tubes.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In which tubes did digestion take place? What evidence do you have?
2. In what way was the enzyme action affected by the presence of hydrochloric acid? By boiling?
3. Why do you think the water bath was needed in this experiment?

FOOD NEEDS

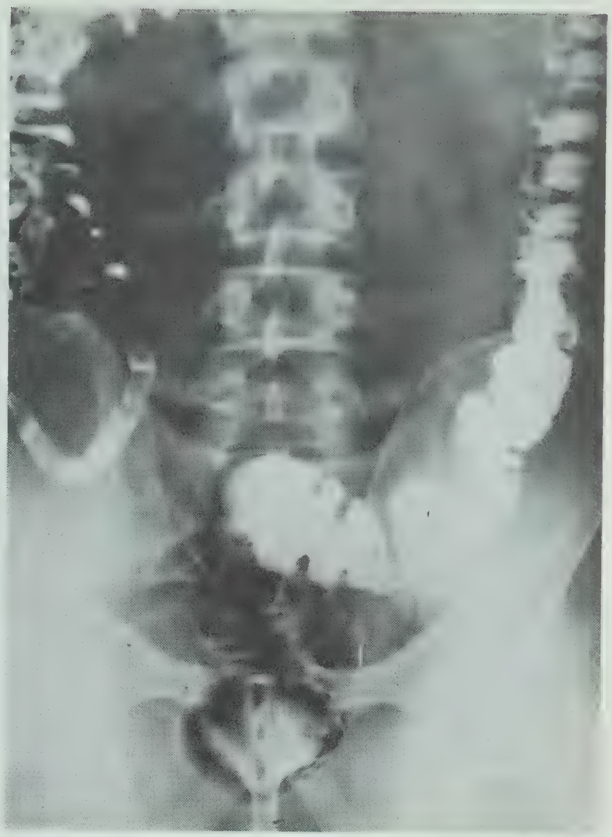
The food needs of people vary considerably. In part, this is explained by age, for a young person of 13 or 14 needs more food than a small child does. So the size of a person is very important in determining his food needs. If the person is active, he is likely to need more food than a person who leads a quiet life. In addition, oxidation rates vary among individuals, and regardless of age, size, or activity, some people use energy more slowly or more rapidly than the average.

Average food needs. The ***Calorie*** (*kal*-or-ee) is the unit scientists use to express the energy value of foods. From age two to five, an average child needs 1,000 to 1,300 Calories per day. Then from six to twelve years, the requirement varies from 1,700 to 2,000 Calories. From ages twelve to sixteen, the required intake varies from 2,000 to 2,600 Calories, being somewhat higher for boys than for girls. For an adult woman, the requirement is about 2,000 to 2,400 Calories, and for an adult man, 3,000 to 5,000 Calories, depending upon the amount of physical labor he does. A farmer, for instance, will generally use a good deal more energy per day than a man who works quietly at a desk.

But remember that the figures in the preceding paragraph are *average needs.* These figures would be lower for a person whose oxidation rate is below normal. They would be higher for a person whose oxidation rate is above the average. This is another case where there is great variation among people.

Even a person who does nothing but keep alive uses a surprising amount of energy. For example, an individual who is asleep uses about 0.45 Calories each hour for every pound of body weight. So if you weigh 100 pounds, you may use up 45 Calories each hour you are sleeping. If you sleep for eight hours your energy expenditure may be about 360 Calories.

If a person's food intake provides more Calories than he uses, he *gains* in weight, because fat is stored in his tissues. If the food intake provides fewer Calories than he uses, the person draws upon his fat and weight is lost.



13–7. An X-ray photograph of an abnormally large appendix. (*From the Technical Instructional File of Jerry Harrity*)

CONTENTS OF COMMON FOODS

Food	Protein %	Carbohydrate %	Fat %	Calories/Pound
Apples	0.3	12.8	0.5	200
Bacon	9.6	0.0	64.0	2,940
Bananas	1.0	20.0	0.5	400
Beans	4.8	21.6	2.3	565
Beef (lean)	19.1	0.0	12.1	886
Bread	9.6	57.3	2.0	1,200
Butter	1.0	0.0	85.0	3,500
Cheese	30.0	0.0	38.0	2,000
Eggs	11.9	0.0	9.3	775
Fish	21.1	0.0	11.5	300
Lettuce	1.0	3.0	0.0	87
Milk	3.0	5.0	4.0	314
Oranges	0.8	12.0	0.0	175
Pork	17.0	0.0	30.0	1,500
Potatoes	1.9	20.0	0.1	350
Rice (boiled)	2.3	23.8	0.1	500
Sugar	0.0	100.0	0.0	1,790
Tomatoes	7.0	4.0	0.0	100

13–8. How would the Calorie needs of the people in these two pictures differ? (*Left, West Virginia Pulp and Paper Company; right, Merritt-Chapman and Scott*)

Variations in foods. The foods that we eat vary considerably in their protein, carbohydrate, and fat content. This is clearly shown by the figures in the table on page 315. If you ate a one-pound meal containing equal amounts of bacon, bread, cheese, and sugar, its value in Calories would be about 1,982. But if you ate a one-pound meal containing equal amounts of lean beef, lettuce, potatoes, and tomatoes, it would provide only about 356 Calories.

By reference to the table you can also see that if you lived largely on bananas, lettuce, rice, and sugar, there would be little protein in your food. In fact, you probably would soon develop a *protein deficiency*. If you are an average person, you need about two ounces of protein per day.

A pound contains 16 ounces, and potatoes are 1.9 percent protein. So you would have to eat almost seven pounds of potatoes per day to get the required two ounces of protein. On the other hand, about 11 ounces of lean beef would provide for your protein needs. Foods that have high protein content include beef, cheese, eggs, fish, and pork.

The importance of roughage. A good deal of the food that we eat contains material that is not digested, because we lack the necessary enzymes. This material is called *roughage,* and it is largely composed of the cellulose from the walls of plant cells. In proper amounts it is useful because it adds *bulk* to the food mass. With roughage present the food mass is likely to pass through the small intestine and large intestine at a *regular* rate, and constipation will probably be avoided.

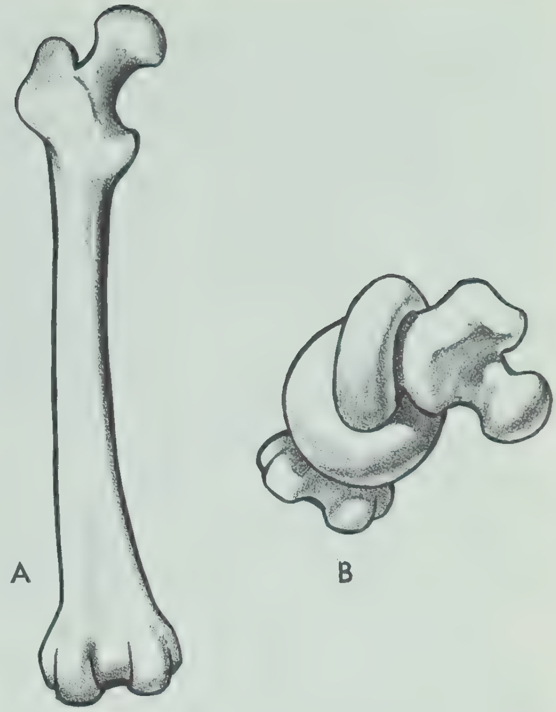
Too much roughage in the food, however, can cause trouble. In this case, the linings of the intestines may become irritated, the wastes remain fluid,

and the condition known as *diarrhea* results.

Spinach is a food that is often eaten to add bulk to the diet. Only about 5 percent of spinach consists of proteins, carbohydrates, and fats, and not all of this can be digested. As a result, pieces of spinach, which are high in water content, remain in the digestive canal and add bulk to the wastes. Various other leafy vegetables, as well as fruits, are good sources of roughage.

Water and minerals. Since protoplasm contains a high percentage of water, it is not surprising that the human body is very sensitive to water shortage. Water is essential to maintain the normal state of the protoplasm in body cells.

We lose water to the air when we breathe, and when we perspire. We also lose water when we discharge wastes. The body must have new supplies to take the place of the water that is lost. These new supplies come in part from the water content of foods, and from the liquids we drink.



13–10. When the minerals have been removed from a bone, the bone can be tied in a knot.

13–9. Do you eat enough foods that contain roughage? How many of the foods pictured above have you eaten today? (*Grant Heilman*)

The body also must have various *mineral* compounds. You know that *calcium* compounds are necessary for bone formation. The blood plasma requires common salt, which is a sodium compound. Iron compounds must be provided for the development of red corpuscles. Iodine compounds assure the health of the thyroid gland. Calcium compounds, iodine compounds, and iron compounds are the mineral compounds needed in the largest amount. We normally get some of our supply of mineral compounds from what we drink, and the rest from what we eat. An iodine compound is often added to the salt that we use on foods.

CARBOHYDRATE DIGESTION

You can obtain a substance from biological supply houses called ***pancreatin*** (*pan*-kree-*at*-un). Pancreatin comes in powdered form, and it contains the digestive enzymes of the pancreas.

STARCH DIGESTION BY AN ENZYME OF THE PANCREAS The pancreas secretes a carbohydrate-splitting enzyme called *amylase*. To test the action of amylase, prepare a digestive fluid in a test tube by dissolving 10 ml of pancreatin in 40 ml of water. Now use a scalpel to obtain scrapings from a piece of raw white potato. Put about 10 ml of the scrapings in the test tube which holds the digestive fluid. Set the tube aside for 40 minutes, so that digestion may proceed. If the amylase acts upon the starch, some of the starch will be changed into sugar.

Prepare a second tube of scrapings, but do not add pancreatin. Now divide the contents of the second test tube into two equal portions. Test one portion for the presence of starch by putting it in a watch glass and adding a few drops of iodine solution. A *bluish-black* color will indicate that starch is still present. Test the other portion for the presence of sugar by adding 5 ml of Fehling's solution A, and 5 ml of Fehling's solution B, and heating until the mixture comes to a boil. A *coppery-brown* color indicates the presence of sugar. After 40 minutes, divide the contents of the first test tube into two equal portions. Test one portion for the presence of starch and the other for the presence of sugar.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did the Fehling's solution test indicate the presence of sugar in the second tube? In the first? If so, what was the source of the sugar?
2. Did the iodine test indicate the presence of starch in the first test tube? In the second? If so, can you think of reasons why this starch was not digested?
3. What environmental factors do you think might affect the action of pancreatin?

THE VITAMINS

In addition to proteins, carbohydrates, fats, mineral compounds, and water, the body must have the food substances known as ***vitamins*** (*vy*-tuh-mins). These vitamins are present in

13–11. Good sources of vitamin A. (*USDA Photo*)

various foods, and if we eat a variety of things, including vegetables and fruits, our bodies usually get the vitamins that they need. But some people tend to eat foods that lack a certain vitamin. When this happens, a *deficiency disease* results.

Vitamin A and eye defects. Vitamin A is present in yellow vegetables and fruits, such as carrots, sweet potatoes, squashes, apricots, cantaloupes, and peaches. It is also represented in liver, the liver oils of fish, butter, milk, and vegetable greens.

Liver and liver oils, however, are the best sources of vitamin A. The livers of vertebrates change ***carotene*** (*karo*-teen), a yellow plant pigment, into vitamin A. Our own livers can do this, if we eat plants that contain enough carotene. Or we can simply get the needed vitamin A from animal tissues and products, such as butter.

Serious lack of vitamin A has harmful effects upon the human nervous system. Less marked effects include a dry and rough skin, and irritation of membranes around the eyes. In addition, the condition known as "night blindness" may develop. A person who is "night blind" does not see as well in partial darkness as a person with normal eyes. See Fig. 13–12 for a photograph of rats with a vitamin A deficiency.

The B vitamins. There are a number of B vitamins that are sometimes called the "B complex." Vitamins of this complex are found in such foods as beans, beef, butter, cabbage, carrots, corn, eggs, ham, kidneys, lettuce, liver, mutton, peanuts, pork, potatoes, rice husks, soybeans, tomatoes, whole wheat and dry yeast.

We shall only attempt to deal with two of the B vitamins at this time. One of them is ***thiamin*** (*thigh*-uh-mun), or

13–12. Left, a white rat with a serious vitamin A deficiency. Right, the same rat with eyes restored to normal by daily feeding of vitamin A. (*Squibb Division, OLIN*)

13–13. Left, a white rat suffering from a vitamin B_6 deficiency, which causes a serious skin condition. Right, the same animal cured by daily doses of vitamin B_6. (*Squibb Division, OLIN*)

vitamin B_1, and its presence in the body is essential to the release of energy from carbohydrates and to the health of the nervous system. In the Orient, a good many people live largely on polished rice. The husks of rice grains contain thiamin, but when the husks are removed in the polishing process, the thiamin goes with them into discard. As a result, people who subsist largely on polished rice develop a deficiency disease called ***beri-beri*** (*berry-berry*). In advanced cases of beri-beri, the limbs become paralyzed, and the heart may be seriously affected.

Outside of the Orient, people are not likely to develop active cases of beri-beri. Sometimes, however, they do have milder thiamin deficiencies. Such people may be unduly irritable, lacking in appetite, unable to sleep well, and subject to constipation.

Another vitamin of the B group is ***niacin*** *ni*-uh-sun). This vitamin acts to prevent the disease ***pellagra*** (puh-*lay*-gruh). The minds of pellagra victims may be affected. Their tongues become sore, and so does the skin around their mouths. Sometimes they have a rash on the backs of their hands. They suffer from indigestion. People who live largely on cornmeal and molasses quite commonly develop pellagra.

Vitamin C and scurvy. Vitamin C is well represented in apples, cabbage, carrots, celery, grapefruit, lemons, lettuce, limes, peppers, potatoes, peaches, pineapples, strawberries, and tomatoes. But vitamin C can be destroyed by too much heat, or can be dissolved out of foods that are soaked for a long time in water.

In the days of long, slow ocean voyages, sailors often developed ***scurvy.*** This disease was also a plague of men who engaged in long overland expeditions, and among the people of nations

13–14. Vitamin C can be found in many common foods. Can you name any other foods high in vitamin C content? (*USDA Photo*)

13–15. The chicken on the right is suffering from a vitamin D deficiency, known as rickets. (*National Dairy Council*)

at war. In 1747, an English doctor suggested that scurvy might be due to lack of fresh fruits and vegetables. He urged that British sailors be supplied with lime juice. This was done, and British sailors have been known as "limeys" ever since. After lime juice was added to their rations, cases of scurvy disappeared.

In mild forms, scurvy is marked by weakness, swollen and bleeding gums, loose teeth, joint pains, and nervousness. If vitamin C is not supplied, the heart may enlarge and undergo changes which result in death. People are not likely to get fatal cases of scurvy today, but it is quite possible to have a partial vitamin C deficiency.

Vitamin D and rickets. Vitamin D is best represented in fish-liver oils, but is also found in butter, eggs, some fresh fish, milk, and oysters. In addition, it is formed from substances in the human skin when the skin is exposed to sunlight.

When children do not receive enough vitamin D, the deficiency disease known as ***rickets*** develops. In this condition bones fail to harden properly, and portions of the skeleton become deformed. The leg bones, for example, may be curved or bowed rather than straight. Bones of the skull, chest, and hips are also likely to be affected.

Other vitamins. There are other vitamins that are lacking in the diets of some people. Among them are vitamin B_2, which prevents certain eye and skin defects, vitamin B_{12}, which prevents anemia and damage to the nervous system, and vitamin K, which is necessary for normal clotting of the blood.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. amino acid	First section of the small intestine.
2. duodenum	Hard outer covering of teeth.
3. enamel	Starchlike substance produced from glucose
4. glycogen	Indigestible part of food.
5. pepsin	Substance that contains a starch-splitting enzyme.
6. roughage	Deficiency disease due to lack of vitamin C.
7. saliva	Stomach enzyme that functions in protein digestion.
8. scurvy	End-product of protein digestion.

B

1. beri-beri	Yellow plant pigment that can be changed into vitamin A.
2. Calorie	Deficiency disease due to lack of vitamin B_1.
3. carotene	Tooth adapted for biting.
4. dentine	Unit used to measure food energy values.
5. villi	An end-product of fat digestion.
6. glycerol	Material that makes up the bulk of a tooth.
7. incisor	Deficiency disease due to lack of vitamin D.
8. rickets	Fingerlike projections on the lining of the small intestine.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The human body has three pairs of salivary glands.
2. The function of the salivary enzyme is to aid in swallowing.
3. "Wisdom teeth" are more properly called molars.
4. Incisors and canines are adapted for biting.
5. Teeth are dead structures and have no blood supply.
6. Cavities in teeth may be enlarged by microorganisms.
7. The diaphragm is located just below the stomach.
8. Stomach gland cells secrete gastric juice.

9. A muscular valve at the end of the stomach controls the movement of food into the small intestine.
10. Most of the chemical changes in digestion take place in the stomach.
11. The end-products of digestion are soluble in water.
12. Liver bile contains a number of different digestive enzymes.
13. Fat digestion takes place in the pancreas.
14. Alcohol may be absorbed by blood vessels in the stomach wall.
15. Glucose provides the main source of energy for body cells.
16. The intestines are normally free of bacteria.
17. From ages twelve to sixteen, boys and girls need only about 1,000 Calories of food energy per day.
18. Potatoes are much richer in proteins than is lean beef.
19. A good portion of the food we eat consists of indigestible material.
20. Calcium and iodine are the only mineral substances known to be needed by the human body.
21. Yellow vegetables, liver, and butter are good sources of vitamin A.
22. Thiamin and niacin are vitamin deficiency diseases.
23. British sailors have been known as "limeys" because for a time lime juice was used aboard British ships to prevent scurvy.
24. Under certain conditions, vitamin D is formed in the human skin.
25. Deficiency diseases cannot develop so long as enough Calories are supplied to the body.

DISCUSSION QUESTIONS

1. In what ways does the human body use food?
2. Why does food have to be digested?
3. In what ways are the human mouth parts adapted to prepare food for digestion?
4. Describe the structure of a tooth.
5. What causes cavities in teeth? What should be done about them?
6. What are the functions of the enzymes formed by the salivary glands? The stomach? The pancreas? The small intestine?
7. Explain how food is moved from one part of the digestive system to the next.
8. What are the end-products of digestion, and how do they get into the blood stream?
9. What happens to simple sugars in the body? Amino acids?
10. What is the function of the large intestine? Why is this important?
11. Why is it that the food requirements of people vary so much?
12. Explain how eating habits are related to gain and loss of body weight.
13. Explain how eating habits may be related to disease.

14. Why is it important to control the amount of roughage taken in with food?
15. What processes tend to decrease the body's water supply? Increase it?
16. In what ways does the human body use minerals? Vitamins?
17. What things are done to food that tend to remove or destroy vitamins?
18. What was the historical relationship between long ocean voyages and the disease called scurvy?
19. What environmental factors are related to the disease called rickets?
20. Explain what is meant by a "balanced diet."

THINGS TO DO

1. Using colored paper outlines to represent body parts, prepare a bulletin-board display of the digestive system. Label each part of the system, and describe how it functions in the digestion of food.
2. Using charts of food values, prepare a list of foods that would supply a one-day balanced diet for an average person in your age group. Prepare other one-day balanced diets for persons who are underweight and persons who are overweight.
3. Write a report on the story behind the discovery of one of the vitamins. Use reference books as a source of information.
4. Make a study of food "fads." Explain how such fads may be dangerous to health.
5. Make a collection of food wrappers and parts of food containers that tell what is in the food. Find out why certain substances are added to foods. Report your findings to the class.

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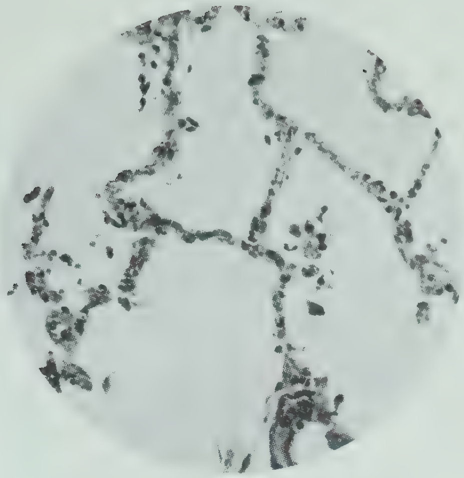


CHAPTER 14

Energy Supply and Waste Removal

Food is the source of energy for organisms, whether it is food that is made by the green plant, or food that is eaten by the animal. In the last chapter, you learned that complex foods must be broken down by digestion, and then delivered to cells of the body. Food molecules are used by the cells to build and repair protoplasm, and to provide the energy that is required to carry on the life processes.

Food is only one of the basic needs of organisms. They must also have supplies of oxygen to break down the foods in the oxidation process. They must have some way to dispose of waste products that are constantly being produced. Oxygen supply and waste removal are two requirements of a good internal environment. In this chapter you will learn how oxygen gets into your blood stream. You will study lung diseases and breathing rates and such structures as the kidneys and skin.

ENERGY SOURCES

Two types of energy release. Yeast cells and some of the bacteria have a special method of breaking down molecules to obtain energy from them. Oxygen from the air is not used in this process. In fact, some organisms of this type can only live well in an environment where there is little or no air. Such organisms are said to be ***anaerobic*** (*an*-uh-*roh*-bik).

But the great majority of living things, including man, have cells which use free oxygen to release energy from food molecules. Organisms which carry on this type of oxidation process are called ***aerobic*** (air-*oh*-bik).

Oxidation in aerobic organisms. The process of breaking down a glucose molecule may be used as an example of oxidation in aerobic organisms. This process takes place in a number of steps. Each step involves one or

more chemical changes. In the end, however, what has happened may be summarized as follows:

Glucose + Oxygen →
Carbon Dioxide + Water + Energy

Or, in chemical terms:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

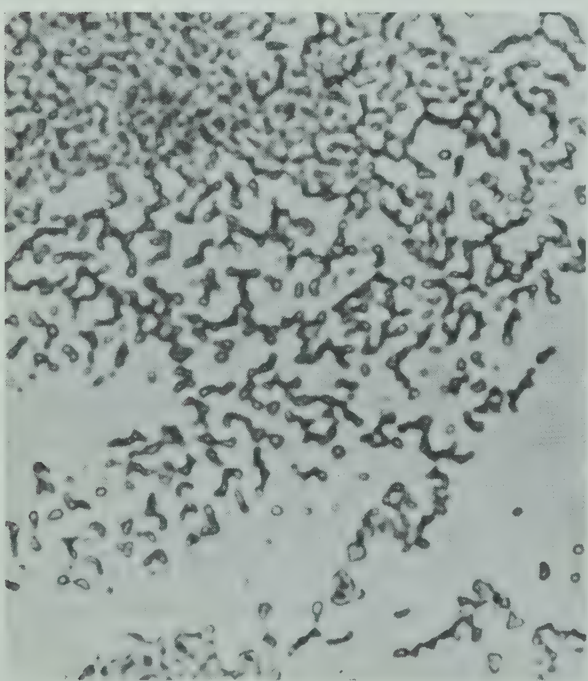
What *ATP* molecules do. The energy released in the oxidation process is largely trapped in *ATP* molecules, which you read about on page 36. These *ATP* molecules then serve as sources of chemical energy for carrying on the activities of cell life. For example, energy may be used to bond together a group of amino acids, and form a particular kind of protein molecule. This protein molecule becomes a part of the living cell.

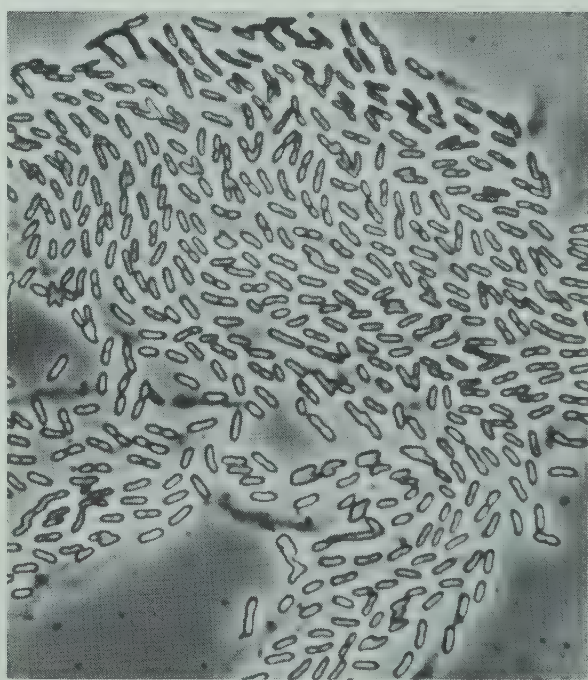
When an *ATP* molecule loses chemical energy and some of its atoms, it becomes an *ADP* molecule. But the *ADP* molecule can become an *ATP* molecule again by recapturing the necessary atoms and chemical energy. Recent studies have shown that *ATP* is formed in a wide variety of plant and animal cells. Within these cells, *ATP* molecules serve as energy trappers, energy transporters, and energy suppliers.

OXYGEN SUPPLIES

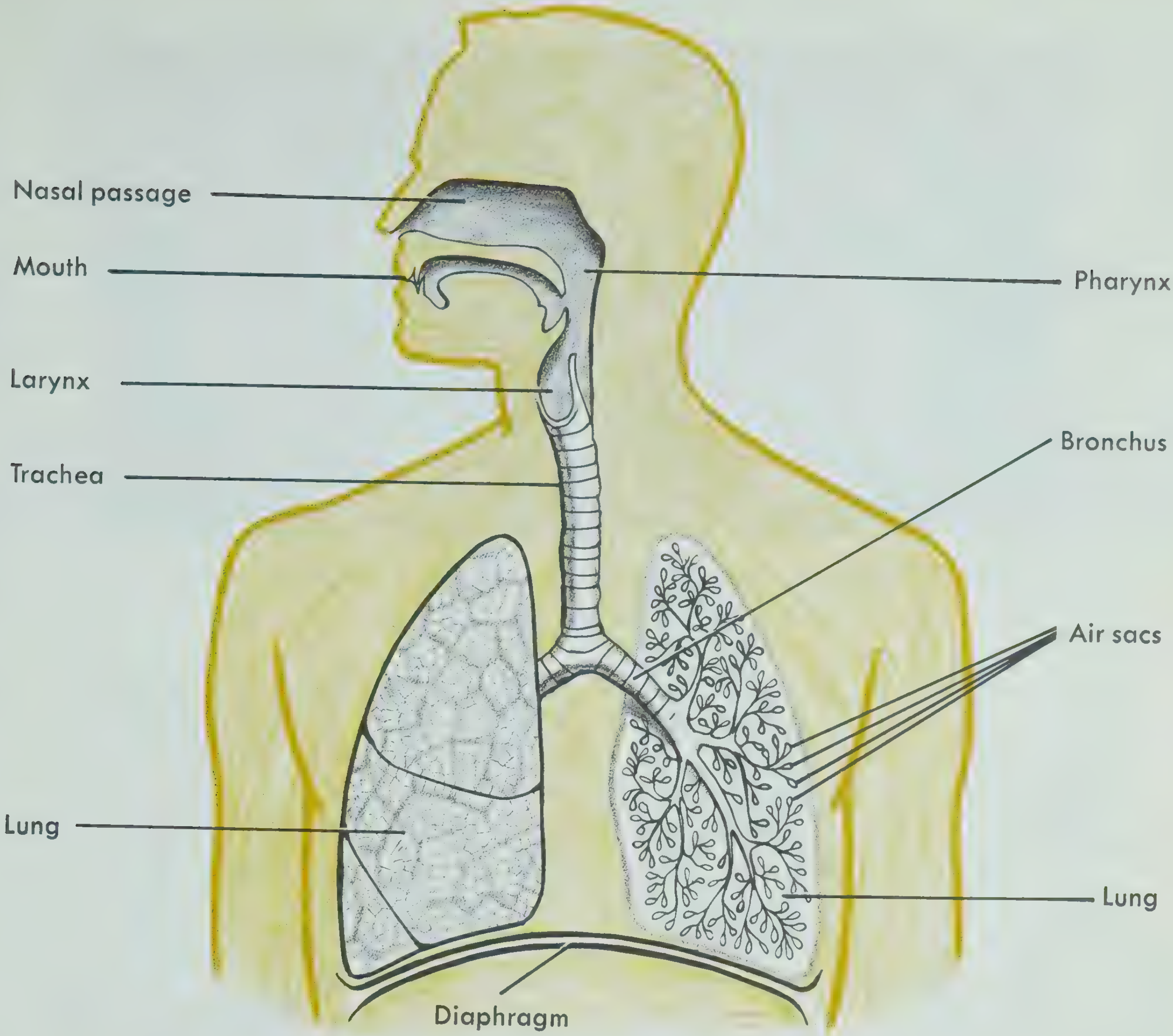
Oxygen is freely available in the air, and is also dissolved in the waters of ponds, streams, and seas. Simple organisms, whose bodies consist of single cells, or a limited number of cells, have no special system for the transportation of oxygen. The oxygen is simply taken in by the individual cells.

But in more complex animals, many cells are too far removed from the surface to obtain oxygen in this manner. In an earthworm, for instance, small blood vessels near the surface of the body





14–1. Left, anaerobic bacteria; right, aerobic bacteria. How would you distinguish between these two types of bacteria? (*Walter Dawn*)

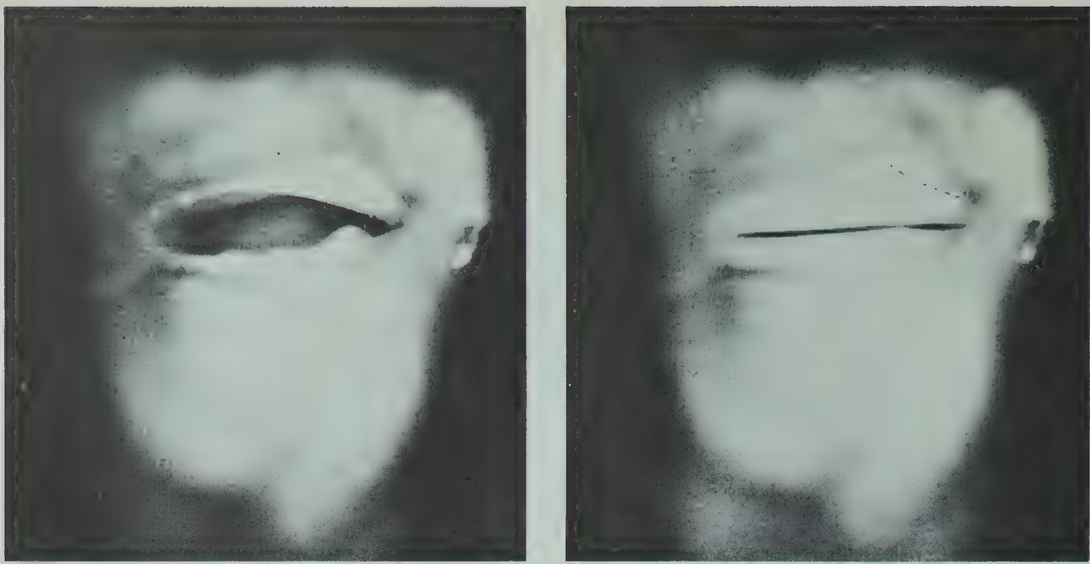


14–2. The human breathing apparatus. Follow the pathway of air through these structures.

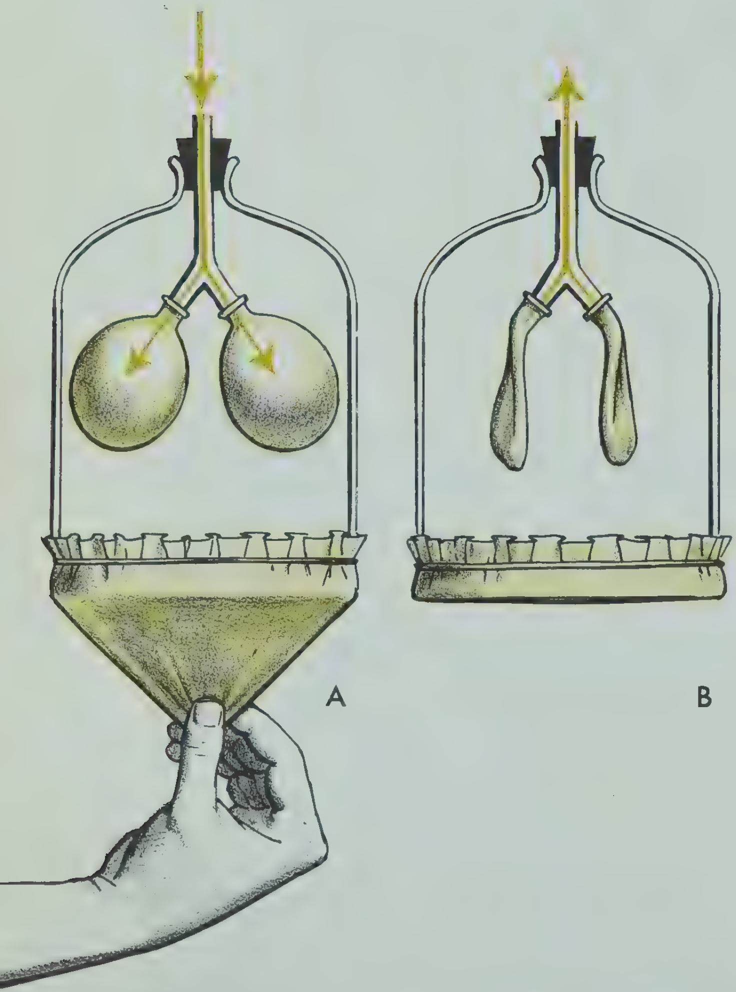
wall take in oxygen and discharge carbon dioxide. Oxygen is then carried to cells of the body by the blood stream. In a crayfish or a bony fish, the blood vessels which take in oxygen from the surrounding water are located in the gills.

Human breathing structures. In mammals, birds, and some other vertebrates, lungs are the organs in which blood vessels receive oxygen supplies. The parts of the human breathing apparatus are shown in Fig. 14–2. Air enters the body by way of either the nasal passages or the mouth. In either case, the air passes back into the pharynx, and then through a small opening into the ***larynx*** (*lahr*-incks). The ***vocal cords,*** which make speech possible, are attached to the walls of the larynx.

From the larynx, air passes through the windpipe or ***trachea*** (*tray*-kee-uh), which gives off a branch called a ***bronchus*** (*bron*-kus) to each lung. The walls of the trachea and bronchi are held open by ringlike supports of *cartilage*. You can feel these rings in the front part of your neck. Each bronchus branches and rebranches within its lung, and gives rise to a great many



14–3. Two photographs showing vocal cord movement. (*Bell Telephone Labs., Inc.*)



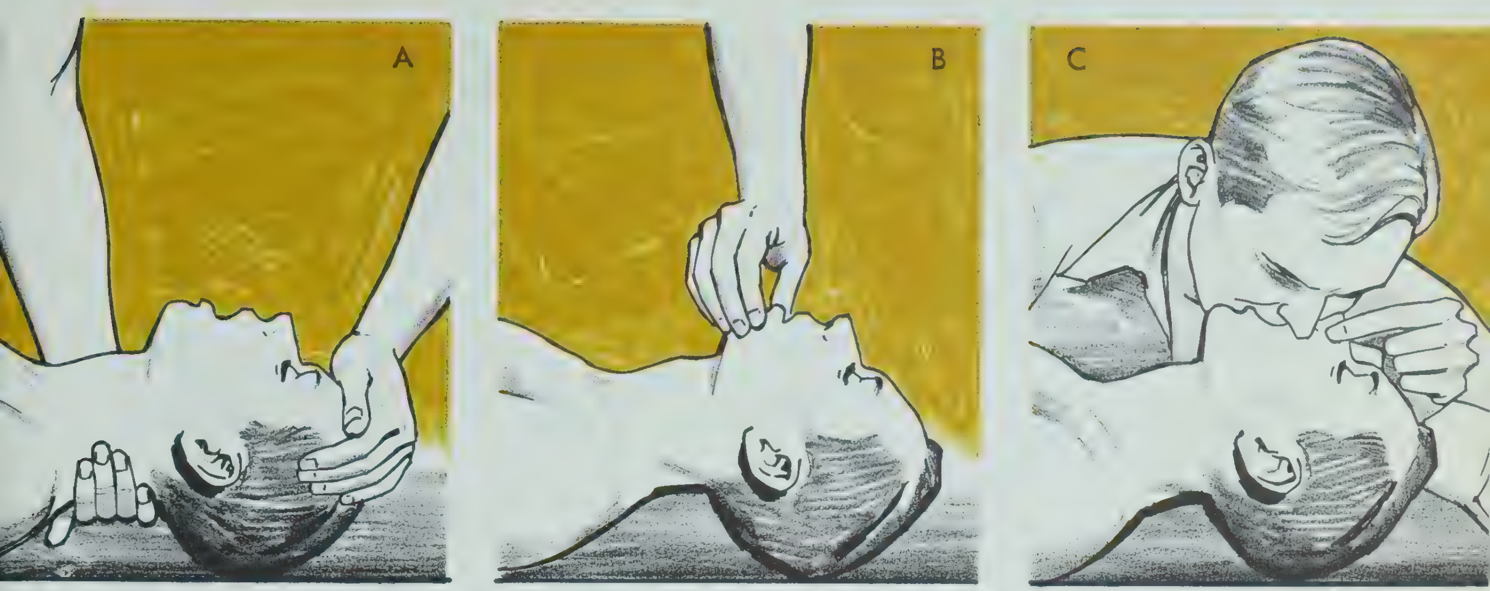
14–4. The apparatus above is called a lung bottle. Can you identify the breathing structures represented by the glass tubing, the balloons, and the rubber sheeting? Are the representations accurate?

small air passages that connect with the ***air sacs.*** Blood capillaries in the walls of the air sacs take in oxygen and discharge carbon dioxide.

Breathing movements. In Fig. 14–2, you can see that the lungs lie in the cavity of the thorax, and above the diaphragm. In fact, they occupy two sealed spaces within the thorax. When these spaces are expanded, the lungs are expanded also, and air enters them through the air passages. When the spaces are contracted, the lungs are also contracted, and air is forced out.

The breathing movements are controlled by the nervous system. When you *inhale,* your ribs are raised and moved outward by muscle action, and your diaphragm is lowered. This causes your chest cavity to expand, and air from the outside rushes into the lungs through the windpipe. Then your ribs and diaphragm return to their former positions, your lungs are contracted, and you *exhale.*

Not all of the air in the air passages is changed each time you exhale and then inhale. If you breathe deeply, about one-half of the air may be



14–5. Steps in artificial respiration. The first two drawings show the correct position of the head; while the third drawing shows mouth to mouth respiration.

changed in a single breathing cycle. But in shallow breathing, as little as one-tenth of the air is changed each time you exhale and inhale.

Artificial respiration. Artificial respiration is sometimes used to revive people whose breathing movements have stopped. This can happen when people inhale too much carbon monoxide, suffer sudden shock or injury, or have been under water too long. The first thing to do is to quickly summon a doctor or an ambulance.

Meanwhile, wipe any dirt or foreign matter out of the victim's mouth. Foreign matter may also be lodged in the breathing passages. In the case of a small child, this matter can often be dislodged by hanging the child's head downward over your lap for a moment or two, and slapping his back between the shoulder blades. An adult may be turned on his side and slapped between the shoulder blades to open up the breathing passages.

Then place an adult victim on his back, as shown in Fig. 14–5. Tilt his head back as far as you can and raise his chin. Pinch his nostrils shut. Make a tight seal with your mouth over the victim's mouth. Blow through the victim's mouth to fill his lungs, and then listen as his lungs contract and the air is exhaled. You should fill his lungs in this manner every five seconds.

If the victim is a child, cover both mouth and nose with a clean handkerchief, and blow through both of these passageways. Do not blow in as much air, and repeat every three seconds.

The victim should be kept as warm as possible, and when he revives he should be kept lying down and resting for at least an hour. Remember that it sometimes takes not minutes, but hours to revive a person.

LUNG TISSUES

If you have a stained section of frog or human lung tissue, you can get a good idea of what lung tissue is like. Focus on the slide with a projector or the low power of a microscope.

A LUNG TISSUE SECTION Remember that your specimen represents a thin slice of lung tissue. You will see many small air spaces, surrounded by walls of lung tissue. The nuclei of some of the cells in the lung tissue stand out clearly. Notice that the walls around air spaces contain elastic connective tissue. These walls also contain many capillaries.

In the tissue section, you will find a number of circular spaces surrounded by heavy walls of muscle tissue. These are cross sections of small veins, small arteries, and the air passages that are given off by a bronchus.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How would you describe the appearance of lung tissue? Does it look like any tissue that you have studied?
2. How does air that is entering a lung get from the bronchus to the air sacs?
3. How is the muscle tissue in a lung related to the process of exhaling air?

RESPIRATION AND DISEASE

Common colds and influenza. Common colds deserve their name, because so many people suffer from them. Of themselves, colds are not dangerous, unless they are followed by a disease, such as ***pneumonia*** (*new*-moan-yuh). Common colds are caused by one or more types of viruses that become established in the linings of the breathing passages. The affected membranes become swollen and sore, and cells of these membranes may discharge a lot of watery mucus.

Common colds generally run their course in a few days. But the same type of cold may affect two people quite differently. When you get a cold, various bacteria in and about your air passages increase in numbers. Their presence adds to your discomfort in various ways, depending upon the particular kinds of bacteria that have become numerous. So two people may have a cold caused by the same *virus,* but one of them has a sore throat and the other one does not.

Influenza (*in*-flu-*enn*-zuh) or "flu," as it is often called, is another disease associated with respiration. It is caused by several types of viruses. Some influenza attacks are relatively mild, but in some years, dangerous forms of the disease have appeared. In such years, many victims of influenza develop cases of pneumonia.

Lung diseases. Until fairly recent times pneumonia was greatly feared, and with good reason. It is caused by over 30 different kinds of bacteria, and at least one type of virus. A pneumonia

14–6. A colony of bacteria which cause tuberculosis. (*Fisher Scientific Co., Electron Optics Division*)

victim has labored and often painful breathing movements, high fever, and is likely to be exhausted. But pneumonia is not as dangerous as it once was. This is because new and more effective drug defenses have been developed. You will read about these new drugs in Chapter 17.

Tuberculosis (too-*ber*-kyoo-*loh*-sus) has been a dangerous disease of man for many centuries. It is caused by one species of bacterium that forms colonies in lung tissues. New drugs to combat tuberculosis have been discovered in recent years, and the search for even better drugs is continuing.

BREATHING RATES

Carbon dioxide waste is formed in larger amounts when you engage in exercise. Following exercise, however, the amount of carbon dioxide in a single breath does not increase as much as you might expect. Instead, the rate of breathing changes. You take more breaths per minute, and as a result, you discharge more carbon dioxide.

AN INVESTIGATION OF BREATHING RATE To make this observation, you should have another student as a partner. Have him sit quietly in a chair with his eyes closed for ten minutes. Then count the number of times he inhales and exhales during a period of a minute. Make three of these counts, and average them. We shall call this average the "normal" breathing rate.

Now have your partner exercise by hopping up and down on one foot 20 times. Then have him sit down, and make three more one-minute counts of his breathing rate. Determine the average breathing rate after this brief exercise.

Have your partner remain seated, and find out how long it takes for his breathing rate to return to normal.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What was the "normal" breathing rate of your partner? The average rate after exercise?
2. How do you explain the increase in the breathing rate?
3. After exercise, how many minutes passed before the breathing rate returned to normal?

KIDNEY FUNCTIONS

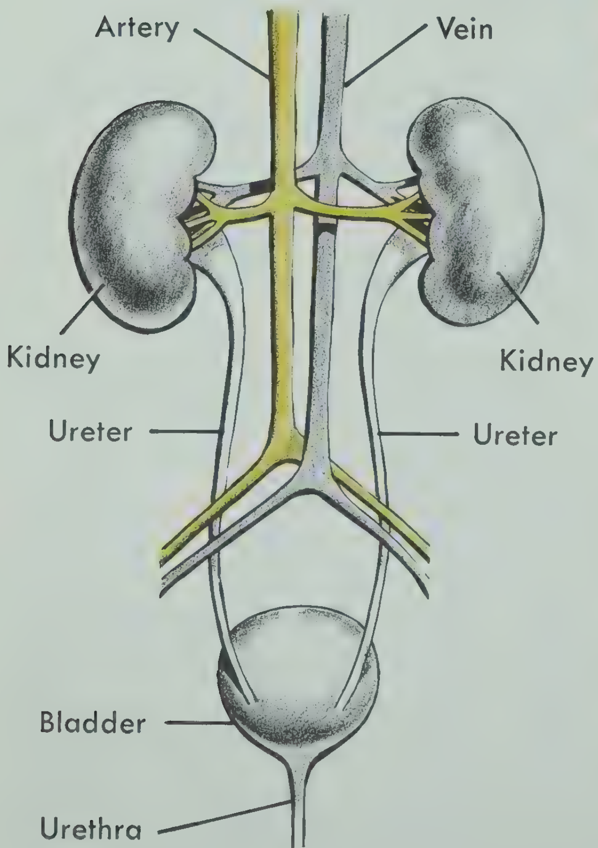
The human kidneys serve to remove protein wastes, salts, and some of the excess water from the body. They are located next to the muscles of the back, in the region of the abdomen, but are actually outside the cavity of the abdomen.

Kidney structures. A diagram of the kidneys and related structures is shown in Fig. 14–7. Each kidney receives blood through an artery, and discharges blood through a vein. There is an extensive capillary network in the kidney tissues. This network comes in close contact with many kidney ***tubules.*** Each tubule removes some liquid waste from the blood, and this waste drains into a cavity near the inner margin of the kidney. From this cavity, the waste passes through a tube known as a ***ureter*** (eu-*ree*-ter) to the ***bladder.*** The bladder discharges the

liquid waste to the exterior through another tube called the ***urethra*** (eu-*reeth*-ruh).

Protein wastes. Protein wastes come from the breakdown of amino acids in cells of the body. One waste so-formed is ammonia. Tissue cells combine this ammonia with one of the amino acids to form a special protein waste, which is discharged into the blood stream.

When this protein waste reaches the liver, it is acted upon by an enzyme of liver cells. It now becomes a substance known as ***urea*** (*eu*-ree-uh). Urea goes back into the blood stream, and is soon carried to the kidneys. Here the urea, along with excess salts and water, is removed from the blood by the kidney tubules. The mixture of water, urea, and salts is called ***urine*** (*yoo*-run).



14–7. A diagram of the kidneys and related structures.

The kidneys in health and disease. The quantity and the color of the urine depends upon a number of factors. One factor is the amount of *water* available for discharge. This, in turn, depends upon how much water a person drinks, and how much he perspires. The kidneys have their most difficult task when they must remove a lot of salt and protein waste. There is additional burden when not much water is available, and in such cases the urine is dark.

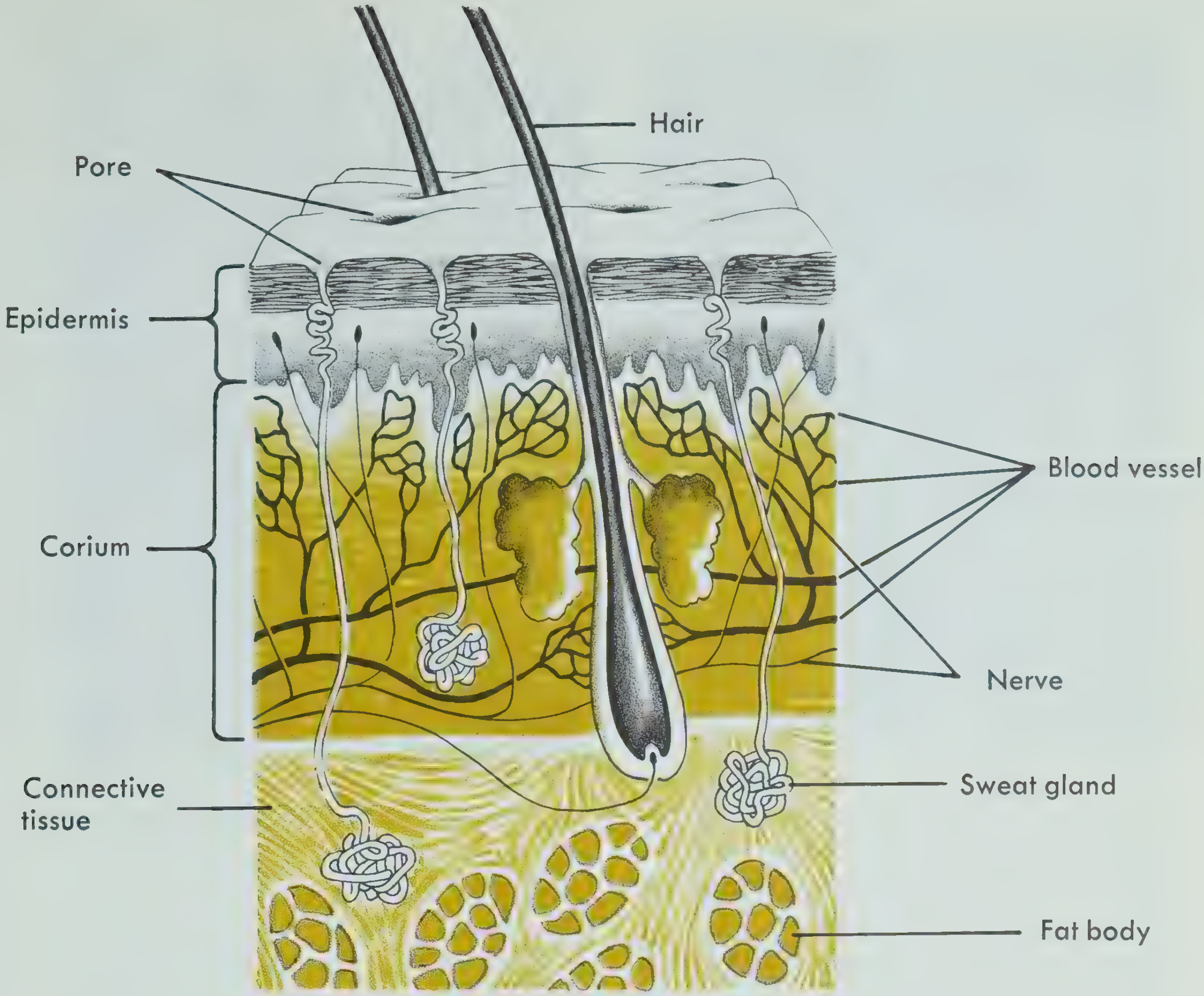
Various poisons, severe exposure, and diseases caused by bacteria are likely to cause kidney damage. Hardening of the arteries in kidney tissue can also cause serious damage. If the damage is extensive it is serious, because it means that the body cannot get rid of protein wastes at a normal rate.

DISSECTING A KIDNEY

Obtain a fresh beef, pork, or sheep kidney. Using a sharp knife, split the kidney through its long axis, so that the cutting plane passes through the ureter at the point that it leaves the kidney.

Examine the split halves of the kidney. Note that the ureter connects with an internal cavity into which the urine drains. From this cavity, the urine drains through the ureter to the bladder. The solid portion of the kidney is largely a mass of tubules, together with some connective tissue and many branch blood vessels.

ANALYSIS Prepare answers to the following questions in your notebook:
1. Each tubule of the kidney receives a



14–8. Diagram of the layers of human skin.

small blood vessel. How do you think this fact is related to the function of the tubule?

2. If the tubules suddenly ceased to do their work, what waste substance would begin to collect in the blood?

THE SKIN

The skin provides a covering for the body, which protects other tissues and keeps them from drying out. At the same time, the skin serves to keep a great many microorganisms out of the body, although some of them do manage to get through the skin barrier. Hair, fingernails, and toenails develop from cells of the skin. The skin has a very important function in disposing of excess body heat. In addition to all this, nerve endings in the skin are sensitive to touch. You are warned when you come in contact with something that is hot, sharp, or otherwise dangerous.

Skin structures. As shown in Fig. 14–8, the skin is composed of an outer layer and an inner layer. Beneath the skin is another layer made up of ***connective tissue*** and masses of ***fat cells.***

The outer skin layer, or ***epidermis,*** is relatively thin. It is really made up of not one, but several cell layers, and the cells at its surface are continually dying and being rubbed off. They are replaced by new cells that form beneath the surface. This outer layer con-

tains no blood vessels, but it does have some nerve endings.

The inner layer of the skin, or the ***corium,*** contains both blood vessels and nerves, as may be seen in Fig. 14–8. Its upper surface is ridged. It is this ridging that causes your fingers to leave fingerprints. In this layer, you find smooth muscle, connective tissue fibers, the roots of hairs, and certain gland structures.

In Fig. 14–8, you can see that the hair root passes clear through the skin and into the connective tissue that lies beneath the skin. But hair is of epidermal origin. An oil gland is attached to the capsule from which the hair grows, and it secretes the oil, which normally appears on hair.

Do you know why some hair is naturally curly and other hair is straight? It all depends upon the little tubes through which the hairs grow up to the surface. If these tubes are circular in cross section, the hairs are straight. But if the tubes are somewhat flattened, they produce curly hairs.

Heat regulation. Blood passing through the inner layer of the skin gives off heat to the outer skin layer. Some of this heat is lost to the air, in the same way that a hot stove loses heat to the air. So the skin has a role in removing excess heat, quite apart from the action of its sweat glands.

The sweat glands are located in the inner skin layer and in the connective tissue beneath the skin. Their ducts open through tiny pores on the skin surface. Sweat glands are most common in the skin of the forehead, palms of the hands, soles of the feet, and in the armpits.

The perspiration that comes from sweat glands is basically water, which contains salts from the blood, and a small amount of urea. You perspire all the time, but often at so slow a rate that the discharge of the sweat glands is not noticeable. As perspiration evaporates on the body surface, it carries away excess body heat.

14–9. A poison ivy plant. Will you be able to recognize this plant when you see it? (*USDA Photo*)

Suppose a human body loses 3,000 Calories of heat in a given day. About two-thirds of this heat simply passes off from the skin surface. Another 500 or more Calories are lost in the evaporation of perspiration. Most of the remaining heat leaves the body in breathing, but small amounts are discharged with the urine and the solid wastes.

SKIN PROBLEMS

Since the skin layer is in direct contact with the outside environment, it is likely to become cut, scratched, and otherwise damaged on many occasions.

14–10. Are you allergic to either of these plants? Left, hay; right, ragweed. (*Left, Grant Heilman; right, Hugh Spencer*)

Most of these injuries are slight, and heal up readily enough, provided disease-producing bacteria do not get into them.

Skin growths. Certain skin growths, however, are not due to the presence of bacteria. Moles, for example, are overgrowths of the cells, that begin in the outer skin layer and extend down into the inner layer. The cells of these moles contain a lot of pigment, which gives them their dark color. If you have a mole, you should not try to pull hairs out of it, or irritate it in any way. Irritation may cause it to grow larger.

Corns are overgrowths of cells that also begin in the outer skin layer. They develop at spots where there is continual irritation due to friction or pressure. The growths sometimes extend down into the inner skin layer. Corns do not have the dark pigments of moles.

Burns and their effects. You can burn your skin by contact with fire, or by being exposed to too much sunlight. If the burn is mild, only cells of the outer skin layer are damaged, and healing is often rapid. Burns that extend to the inner skin layer are much more of a problem. For one thing, there is always the possibility that they will be invaded by dangerous bacteria. And if the inner skin layer is destroyed, the injury may heal, but unless properly dealt with, it is likely to leave a scar. Burns that extend to the inner skin layer should be treated by a physician.

Poison ivy and allergies. Another common type of skin problem is caused by contact with poison oak or poison ivy. The substance that causes trouble is a protein produced by the plants. This protein is in tiny droplets of plant oil that cover the leaves and stems. When you touch an ivy plant, some of the oil droplets adhere to your skin. In fact, they adhere so strongly that ordinary washing with soap and water may

fail to remove them. A better plan is to swab the affected area with a cloth soaked in rubbing alcohol, and then wash it thoroughly.

The skin rash caused by poison ivy is due to the fact that the person has an ***allergy*** (*aller*-gie). Allergies are reactions to certain specific proteins. Some of these proteins are on things, like poison ivy leaves, that come in contact with the skin. Others are proteins in substances people inhale, such as some of the plant pollens. Still others are proteins in the foods people eat.

You may be quite sensitive to poison ivy, and another person may be unaffected by this particular protein. But a very good thing to remember about allergies is that they come and go. Thus, you may be sensitive to a certain protein for a period of time, and then discover that you are no longer sensitive to it, or vice versa.

Blackheads and acne. Blackheads are a great nuisance to young people. However, there is one good thing about them: they tend to disappear as you grow older. A blackhead is really a growth of skin cells that forms where a duct from an oil gland reaches the skin surface. Such a blackhead blocks the oil duct for the time being, but generally does not destroy the oil gland.

When you have a lot of blackheads, the condition is known as ***acne*** (*ack*-nee). In a bad case, microorganisms may get into some of the oil glands and cause infections. An infected oil gland may become a center from which a *boil* develops. In these bad cases, treatment by a physician is necessary.

Mild cases of acne are very common. One measure that helps is to wash the affected skin area with soap and warm water. Face lotions and salves that contain oil should not be used. Too much oil is present already. In fact, adults who work with machines and get oil on their hands sometimes develop cases of *oil acne.*

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do the same for part *B*.

A

1. allergy	A mixture of water, urea, and salts.
2. anaerobe	Condition caused by a reaction to a specific protein.
3. *ATP*	Type of organism that can live without oxygen.
4. kidney	Molecule that supplies energy for life processes.
5. sweat gland	Organ that functions to remove wastes.
6. ureter	Tube leading from a kidney to the bladder.
7. urine	Skin structure that regulates body heat.
8. epidermis	Outer layer of the skin.

B

1. aerobe	Waste substance removed by the lungs.
2. carbon dioxide	Inner layer of the skin.
3. larynx	Type of organism that uses free oxygen.
4. mole	Cause of the common cold.
5. pneumonia	Pigmented overgrowth of skin cells.
6. urethra	Structure in which vocal cords are located.
7. virus	Tube that connects the bladder to the outside of the body.
8. corium	Lung disease that sometimes follows influenza.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Some organisms can exist only in an environment where there is little or no oxygen.
2. In man, oxygen is necessary for the breakdown of glucose molecules.
3. Energy released from the breakdown of glucose molecules is trapped in molecules of *ATP*.
4. Most single-celled organisms have a special system for carrying oxygen to various body parts.
5. Earthworms breathe by means of tiny lungs in their body cavities.
6. A gill in a crayfish or a bony fish is called a bronchus.
7. In the lungs, oxygen and carbon dioxide are exchanged through the walls of the air sacs.
8. When the diaphragm is lowered, the lungs are contracted and when the diaphragm is raised the lungs are expanded.
9. Each time you inhale and exhale all of the air in your lungs is changed.
10. In artificial respiration, the lungs of an adult should be filled with air every five seconds.
11. It may take many hours to revive a person whose breathing has stopped.
12. Common colds are caused by exposure to cool air, which affects membranes so that they become sore and swollen.
13. Influenza is known to be caused by a particular kind of bacterium that lives in lung tissue.

14. Kidneys function to remove protein wastes, salts, and excess water from the body.
15. A kidney receives blood through a vein and discharges it through an artery.
16. Although urea is produced in the liver, it leaves the body as part of the urine.
17. Hair and fingernails are produced by skin cells.
18. The outer layer of skin is continually being rubbed off.
19. Hair is curly or straight depending upon the shape of the little tubes through which it grows to the surface of the skin.
20. Normally, most of the heat lost by the body leaves due to the action of sweat glands.
21. In addition to water, perspiration contains salts from the blood and a small amount of urea.
22. Poison ivy skin rash is due to tiny thorns that cover the plant's leaves and stems.
23. Allergies usually are associated with particular protein substances.

DISCUSSION QUESTIONS

1. What cell needs are supplied by food?
2. Distinguish between anaerobic and aerobic organisms.
3. What is meant by "oxidation of a glucose molecule"?
4. What is the relationship between an *ATP* molecule and an *ADP* molecule?
5. Explain how the body cells of each of the following obtain oxygen: single-celled organism, earthworm, mammal.
6. List the structures of the respiratory system through which air passes as it moves from the outside to the circulatory system.
7. Explain what happens when you inhale and exhale.
8. Explain how artificial respiration is used to revive a person whose breathing has stopped.
9. What may happen to produce complications following an attack of the "flu," or a common cold?
10. Why does carbon dioxide form in larger amounts following exercise, and how is it removed from the body?
11. Describe the parts of a human kidney and their functions.
12. Explain how protein wastes are removed from the body.
13. What factors affect the nature and amount of the urine?
14. Why is kidney damage considered to be such a serious condition?
15. Describe the skin layers and their functions.
16. What factors act to decrease body heat? Increase body heat?
17. Distinguish between a "mole" and a "corn" on the skin.

18. Why are burns that extend into the inner skin layers so serious?
19. Explain what happens when someone comes in contact with poison oak or poison ivy? What can be done to prevent a skin reaction?
20. What are allergies, and how can allergic reactions be avoided?

THINGS TO DO

1. The organisms that cause tetanus ("lockjaw") and botulism (a very dangerous form of food poisoning) are anaerobic bacteria. Using reference books as a source of information, find out what you can about these bacteria, the diseases they cause, and how the diseases can be prevented.
2. Using colored construction paper, prepare a bulletin-board display to illustrate the differences between the respiratory structures of an earthworm, a crayfish, and a man. Label each part, and indicate the role it plays in supplying oxygen to body cells.
3. Moisten the back of one of your hands with water. Moisten the back of your other hand with alcohol. What difference do you note? How can this differenee be explained? What does this have to do with the study of body temperature control?
4. Prepare a report on one of the following diseases:
   Common cold
   Influenza
   Pneumonia
   Tuberculosis
   Include a section on the cause of the disease, its symptoms, treatment, and prevention.
5. Find out the leading causes of death for persons in this country 50 years ago. Compare these with the leading causes of death today. How can these differences be explained?

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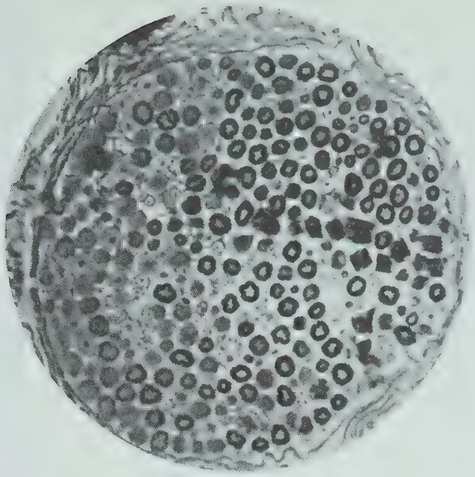
CHAPTER 15



Body Controls

The body of a complex animal makes a great many different kinds of responses. Some responses are to things and forces outside of the body. When you see a car coming toward you, for instance, you respond by getting out of the way. But there also are responses that relate to what happens within your body. For example, when food enters your stomach, the stomach glands respond by secreting digestive fluid.

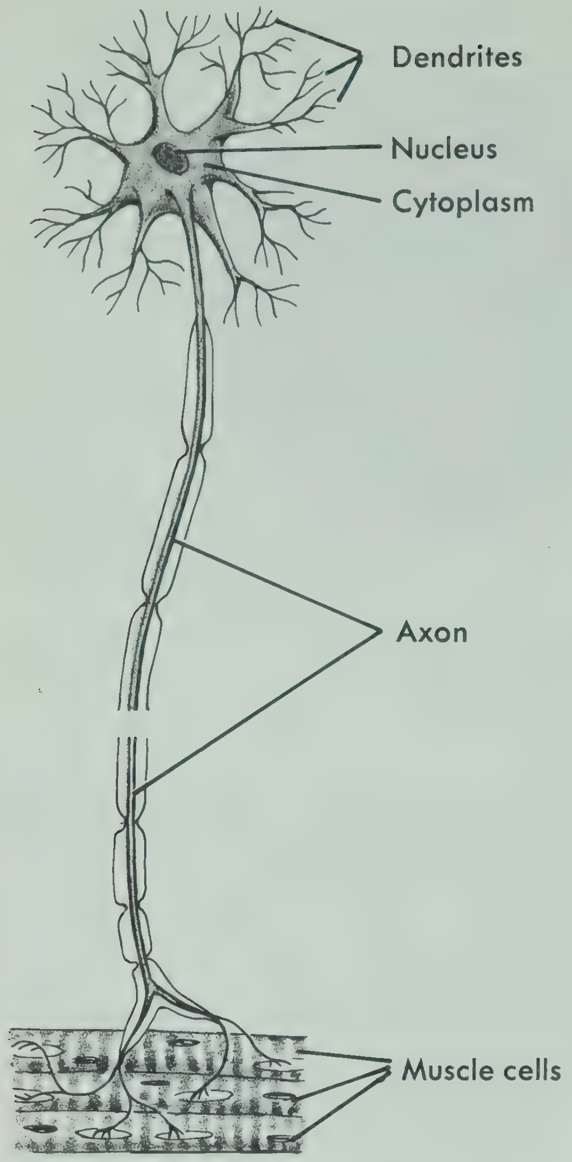
It is fairly obvious that many human responses are under some sort of control. Otherwise, your muscles and skeleton would not work together to move your body out of the path of an oncoming car. Controls of this sort are exercised by the brain and other parts of the nervous system.

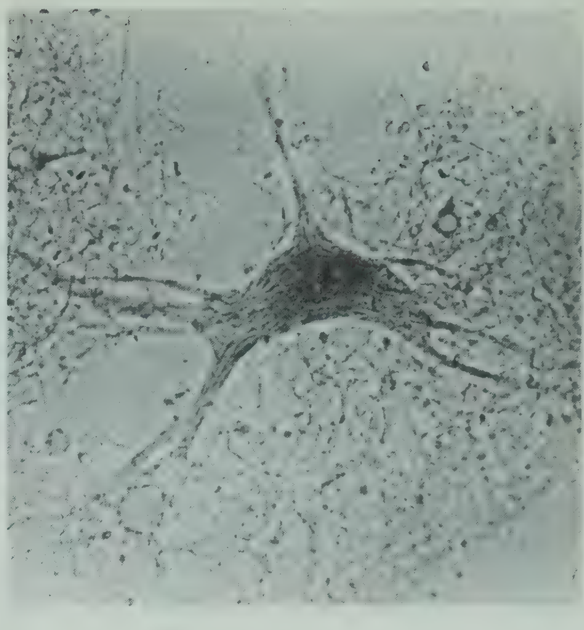
All of the things a person does are part of that person's behavior. They include acts that are *voluntary* or conscious, and acts that are *involuntary* or automatic. Thus, when you decide to cross a street and do so, it is a voluntary act. When your stomach cells begin to secrete gastric juice, however, you have not consciously caused them to do so, and the act is involuntary. There are also some acts, such as breathing, that are basically involuntary, but can be made partially voluntary. An example is the case in which you decide to "hold your breath" for a few moments.

NERVE CELLS AND NERVES

To understand how the nervous system operates, it is necessary to know some things about nerve cells and nerves. A nerve cell is called a ***neuron.*** Fig. 15–1 shows one type of neuron, a type known as a ***motor nerve cell.***

Motor nerve cells. A motor nerve cell has the special function of carrying messages. As you can see in Fig. 15–1(left), this cell has a nucleus and a cytoplasm like many other cells. The cytoplasm bears a number of threadlike projections, the ***dendrites*** (*den*-drytes). It is these rather short dendrites that receive incoming messages.



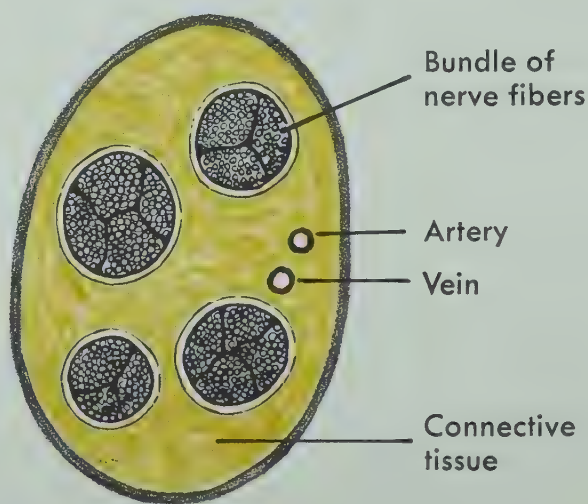


15–1. Left, diagram of a motor nerve cell; right, photograph of motor nerve cell magnified 400 times. (*Walter Dawn*)

When the motor nerve cell receives a message through its dendrites, another message moves out through its rather long ***nerve fiber.*** This nerve fiber is a process of the cytoplasm that is also known as an ***axon.*** It is very slender, but it may be two or three feet long. At its end the axon makes contact with a number of muscle cells. The muscle cells receive the message, and respond by contracting and causing movement of some body part.

You should remember one interesting thing about motor nerve cells: they conduct messages in only *one direction.* Thus, the cell, shown in Fig. 15–1, receives messages only through its dendrites. It sends out messages only through its axon.

Nerve cells and nerves. Various nerves in the human body are large enough so that you can easily see them. What makes up such a nerve? The answer is shown in Fig. 15–2. Much of the nerve consists of *connective tissue.* Within the protective sheath of connective tissue are several bundles of nerve fibers or axons. Small blood vessels are also present within the nerve.



15–2. Cross section of a nerve.

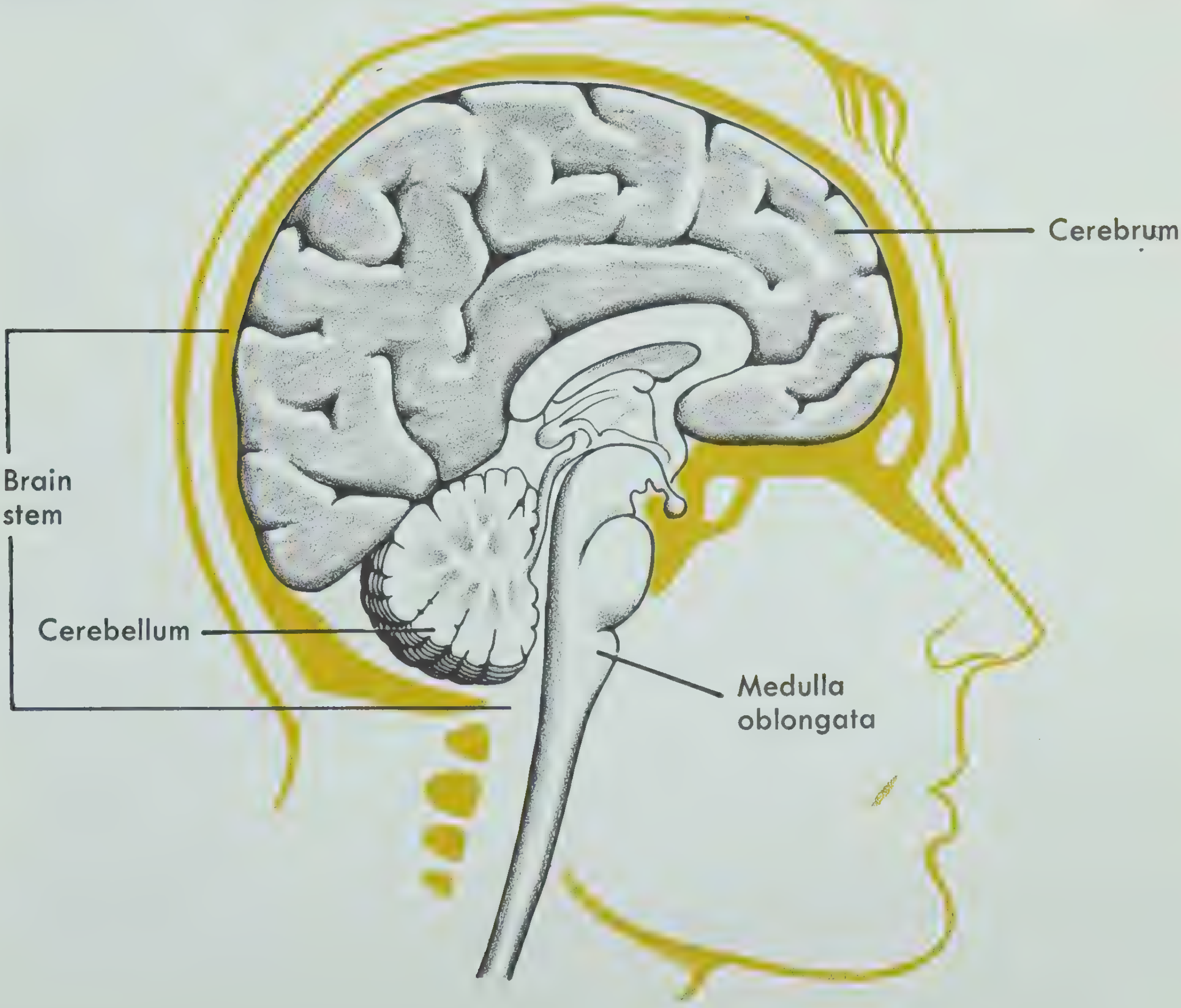
The cell body you see in Fig. 15–1 (left) is located in a nerve center. All around it are many other similar cell bodies. The axons which come from these cell bodies are grouped together in a nerve. This nerve runs from the nerve center to a muscle tissue in some part of the body. So the nerve cells in the nerve center, sending out impulses through the axons in the nerve, control the actions of the muscle tissue.

THE BRAIN AND SPINAL CORD

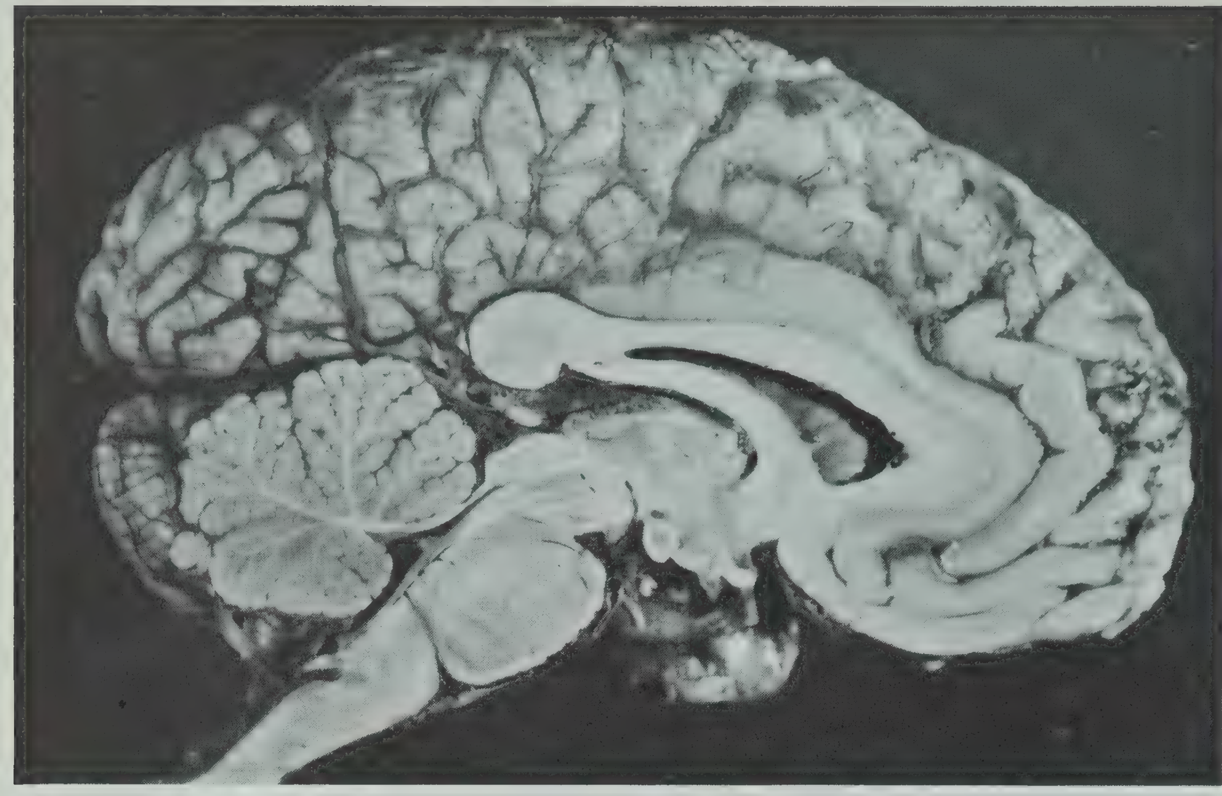
As in other vertebrates, the brain and spinal cord are our highest centers for nerve control. The human brain, however, is far better developed than the brains of other vertebrates. This brain has made man the dominant form of life on the earth.

The human brain. Fig. 15–3 shows a section through the middle axis of the human brain. The brain consists of three main parts that are grouped around a central structure, the ***brain stem.*** This brain stem is largely made up of nerve fibers that carry messages to and from other areas of the brain.

The ***cerebrum*** (*seh*-ruh-brum) forms the largest portion of the brain. As you see in Fig. 15–3, its surface bears many folds. The cell bodies of the cerebrum are largely out near its surface. A folded surface provides more space for these cell bodies than a smooth surface would.



15–3. Diagram of the human brain.



15–4. Can you identify the structures in this photograph of the human brain? (*Joseph James*)

The cerebrum is the highest control center of the brain. You use it when you think, and when you remember past events. You use the cerebrum when you decide to carry out some voluntary act. Some of the cells in the cerebrum receive the messages that come from your ears and eyes. Conscious acts, such as speaking, singing, or walking across a room to get a book are controlled by the cerebrum.

The ***cerebellum*** (*ser*-uh-*bell*-um) lies behind and below the cerebrum. The function of the cerebellum is to control the actions of various muscles. In particular, it is the center responsible for body balance. Such controls are of the automatic or involuntary type.

The ***medulla*** (muh-*duhl*-uh) forms the connection between the rest of the brain and the spinal cord. It is really the hind portion of the brain stem. Impulses from the brain centers pass through the medulla to the spinal cord, and from the spinal cord to the brain. Despite the fact that it is part of the brain stem, the medulla does regulate certain involuntary processes, at least in part. It regulates the tone of blood vessels and the breathing motions.

Twelve pairs of ***cranial nerves*** arise directly from the brain. Among them are nerves that enable us to smell, taste, see, and hear. Some of these nerves from the brain, however, have branches that lead to structures in the neck and the trunk of the body.

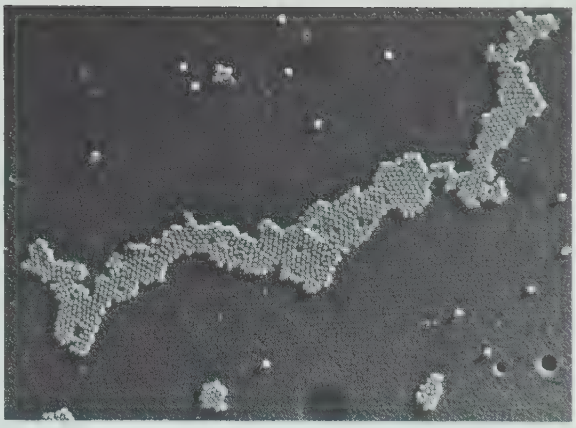
The ***spinal cord*** passes down through the backbone. It is an important pathway through which messages move to and from the brain, and to and from structures in all parts of the body. Thirty-one pairs of ***spinal nerves*** arise from the spinal cord, and their branches reach such organs as the lungs, stomach, intestines, and kidneys. Nerve cells in the spinal cord and

nearby nerve centers control many automatic acts of the internal organs.

Injuries to the brain and spinal cord. Polio is one of the dreaded diseases that causes damage to the nervous system. Nerve tissues do not repair themselves as other body tissues do. So when nerve control centers are damaged by polio, various muscles controlled by these nerve centers may become paralyzed. Some recovery may take place later on, if other nerve control centers "take over" the control of the paralyzed muscles.

Polio is a disease caused by a virus. There are other diseases of the nervous system that are caused by microorganisms. However, the nervous system may also suffer mechanical injury.

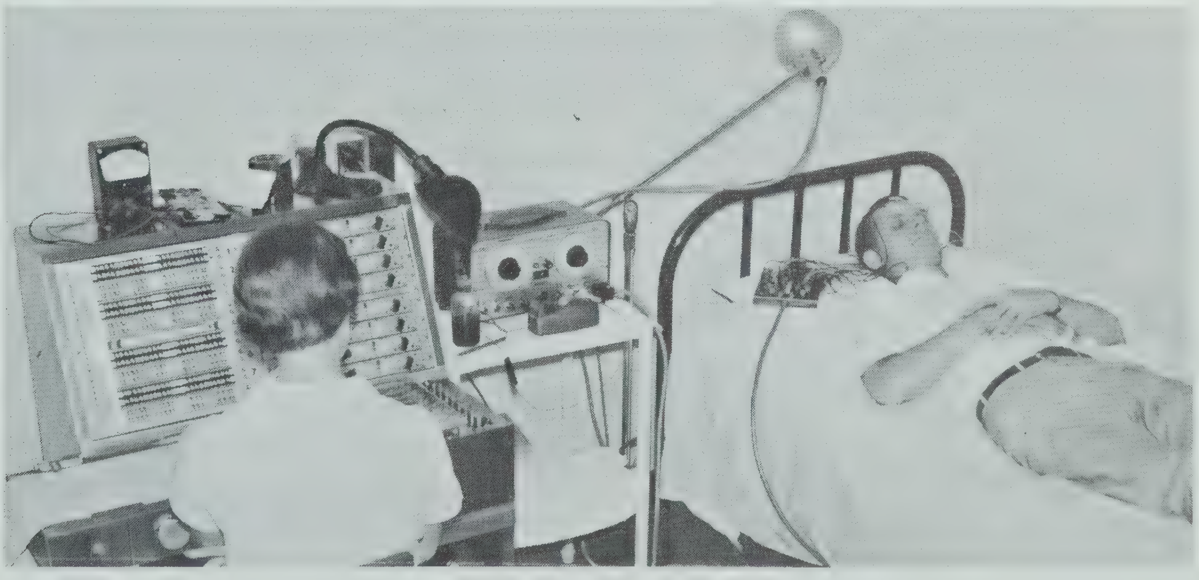
For example, blows on the head may produce lasting damage. Even a series of light blows may rupture or break open a number of small blood vessels in the brain. The blood that escapes presses upon brain tissues, and various brain cells may be prevented from doing their work. Of course, a heavy blow on the head may cause a skull fracture. It may also paralyze vital nerve centers so that death occurs.



15–6. The virus that causes polio. (*A. R. Taylor, Parke Davis and Co.*)

THE ANIMAL BRAIN

Obtain a fresh pig or sheep brain. Examine it to locate the cerebrum, medulla, and cerebellum. Note the many folds in the surface of the cerebrum. Using a sharp knife, slice the brain in half through its long axis, and then slice it from top to bottom. Now you can see how the cerebrum and cerebellum are related to the brain stem.



15–5. The electroencephalograph records a patient's brain waves. (*Grass Instrument Company*)

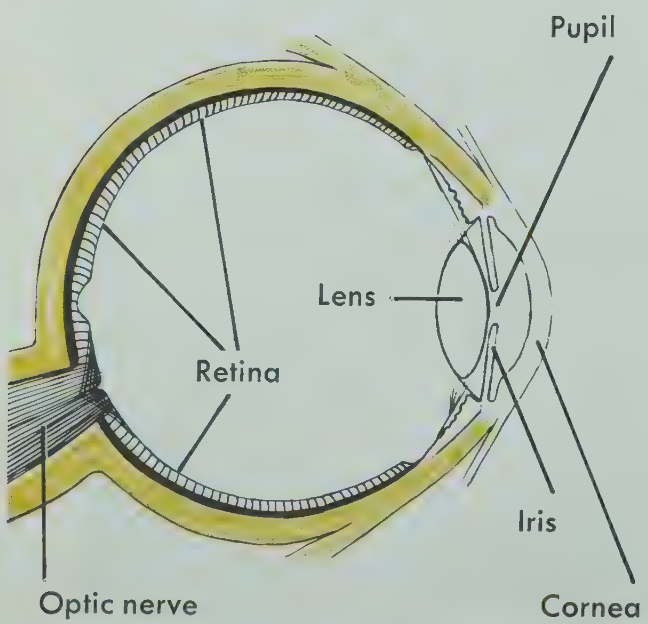
Make a cross section of the cerebrum at about its mid-region. Examine the cut surface and observe that there is grey matter (made up of cell bodies) out near the surface, and white matter (made up of nerve fibers) at a deeper level.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What do you think is the main function of the brain stem?
2. Describe the grey matter and the white matter. How are they related?
3. How does a folded surface of the cerebrum provide for more cell bodies than a smooth surface? How might this be related to intelligence?

SIGHT AND HEARING

Sight and hearing are two of the special senses that we depend upon in order to know what is happening in our environment.



15–7. A diagram of the human eye.

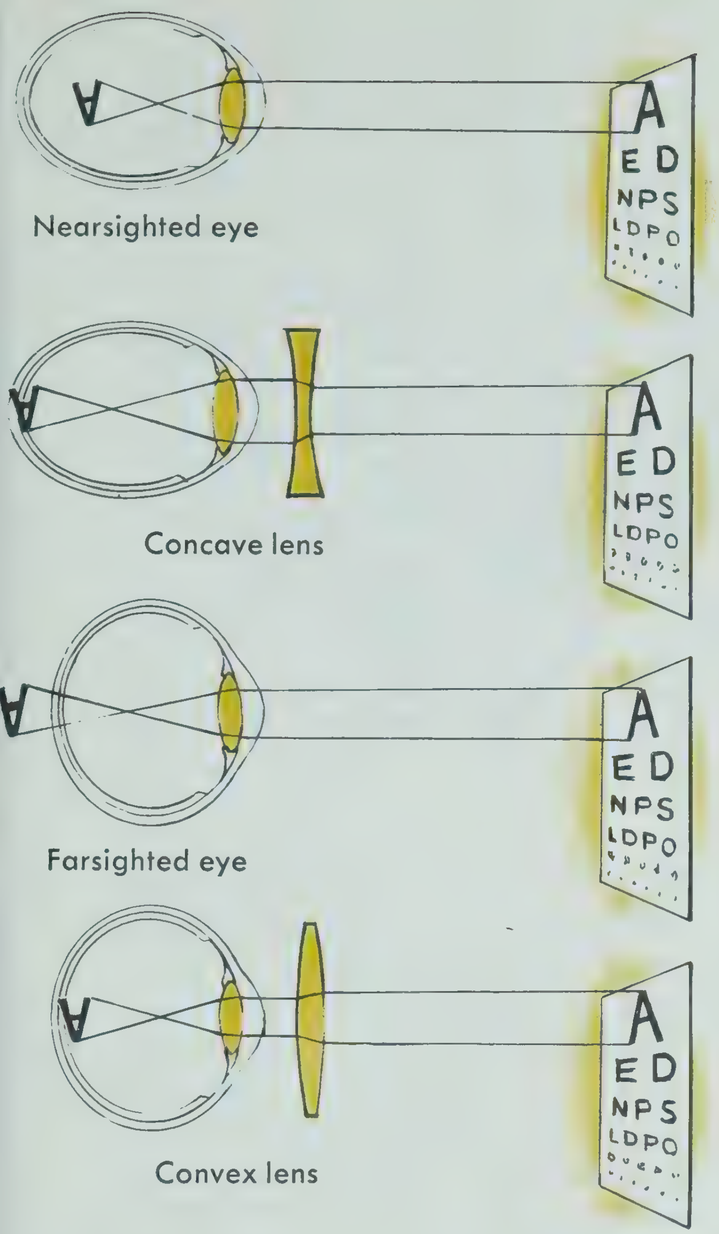
The human eye. Structures of the human eye are shown in Fig. 15–7. Two of the nerves that arise directly from the brain are the nerves of sight or the ***optic*** (*op*-tik) ***nerves.*** One optic nerve connects with each eye. Look at this connection in Fig. 15–7. You see that the optic nerve makes contact with an eye layer called the ***retina*** (*ret*-nuh). The retina lines the back of the eyeball, and its cells are sensitive to light. That is, they respond when light strikes them. From the retina, nerve messages pass along the optic nerve to a sight center in the brain.

When you look at your eye in a mirror, you see a hole or ***pupil*** in the center, surrounded by a colored area which may be blue, grey, brown, or many shades of these colors. This colored area is the ***iris*** (*eye*-rus). In Fig. 15–7, you see that the pupil is really a hole in the iris. In bright light the iris *contracts* until the pupil is quite small, but in dim light the iris *expands* and the pupil becomes much larger. These changes in the size of the pupil are *involuntary acts.*

The white portion of the eye around the iris is an outer protective layer of the eyeball. It is continuous with a transparent portion called the ***cornea*** (*kor*-nee-uh), which lies in front of the iris and the pupil.

The ***lens*** of the eye is suspended a short distance behind the pupil. Muscles in the eye can cause the lens to change its shape. Changes in lens shape serve to focus images on the retina. When a normal eye is focused on a distant object the lens is flattened out. When it is focused on a nearby object the surface of the lens is more curved.

Not all human eyeballs are the same shape, and this is one reason why some people are nearsighted while others are



15–8. Where does the image tend to focus in the nearsighted and farsighted eye?

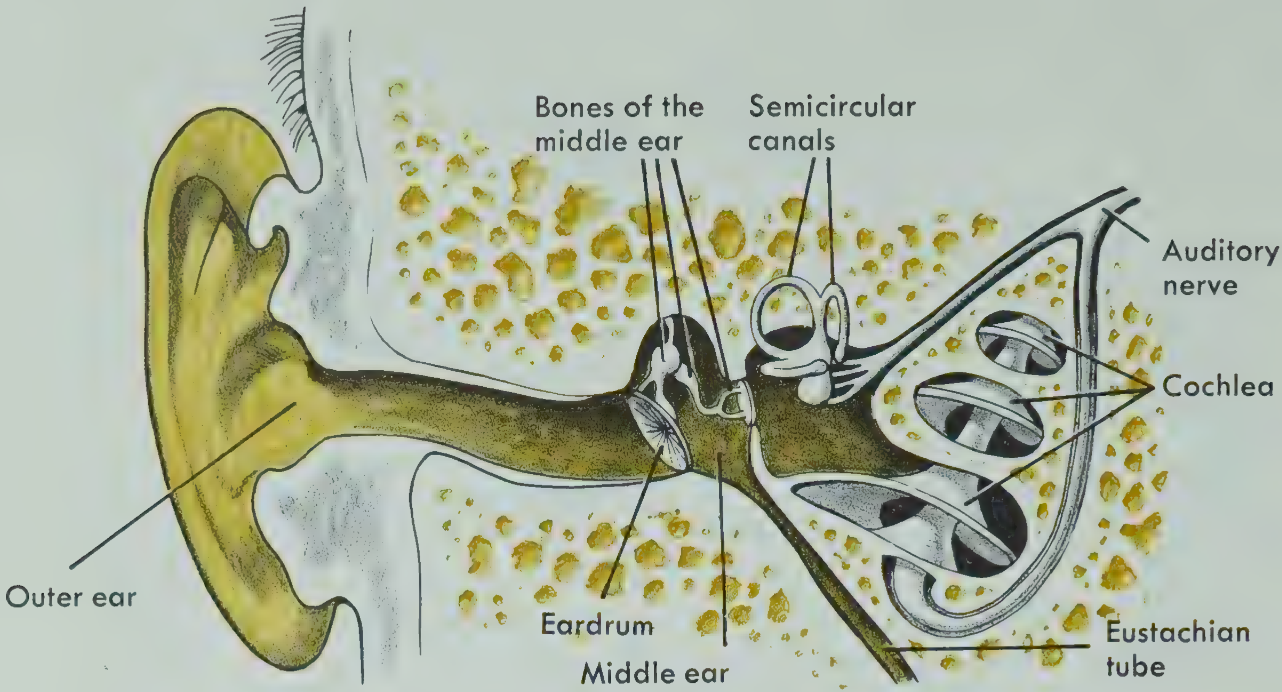
farsighted. In a nearsighted eye, the distance between the lens and the retina is too great, and the image tends to focus *in front* of the retina. This condition is corrected by wearing eyeglasses that have concave lenses, as shown in Fig. 15–8. In a farsighted eye, the distance between the lens and the retina is not great enough, and the image tends to be focused *behind* the retina. This farsighted condition is corrected by wearing eyeglasses that have convex lenses.

Abuse of the eyes. One common abuse of the human eyes is trying to read in light that is too dim. To read without strain you need the light from a 100-watt bulb at a distance of two feet or less. On a clear day outdoors, you would have no problem of dim light, for even in the shade there is sufficient light. Out-of-doors, however, you might encounter glare from sand, ice, or snow. Three things to remember in order to protect your eyes are to make sure you have enough light to read by, to rest the eyes occasionally when you are reading, and to protect the eyes from excessive glare by wearing sunglasses.

The human ear. The ears and the brain centers associated with them make it possible for us to hear and interpret sound waves. As shown in Fig. 15–9, the more important ear structures are located in bones of the skull, with an outer ear passageway that connects with the exterior. Sound waves enter this passageway, and strike the ***eardrum,*** which is stretched across the entrance of the middle ear.

Three small bones extend across the middle ear to bridge the gap between the eardrum and the entrance of the inner ear. When the eardrum vibrates, the vibration is carried to the inner ear by the three small bones. Note in Fig. 15–9, that a small tube leads downward from the middle ear. It is the ***eustachian*** (yoo-*stay*-shun) ***tube,*** and its other end opens into the ***pharynx.*** This tube makes it possible to have air pressure about equal on each side of the eardrum.

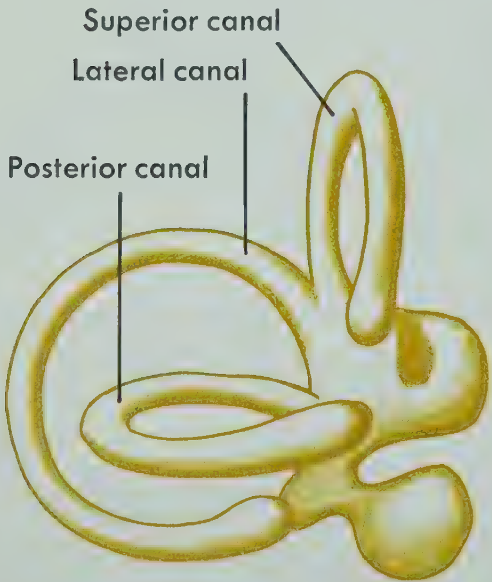
The ***cochlea*** (*kok*-lee-uh) is the hearing center whose cells communicate with the brain. It is filled with fluid, which is caused to vibrate when the vibrations from the eardrum reach



15–9. A diagram of the human ear.

the opening of the inner ear. Impulses from cells of the cochlea pass along the ***auditory nerve*** to the brain.

Another structure of the inner ear is a group of ***semicircular canals.*** Nerve cells in these canals have to do with *balance* rather than hearing. These cells are part of the control system which enables you to tell whether you are standing up or lying down.



15–10. The semicircular canals help us maintain our sense of balance.

Ear damage. Since most of the sensitive ear structures are lodged in bone, you might think them to be well protected. And so they are—against some kinds of injuries. But microorganisms can get into the ear by way of the blood, or through the eustachian tube. They can also enter through the outer ear. When some of these microorganisms form colonies in ear structures, the result is likely to be a painful earache, and permanent damage may be done to the sense of hearing. A doctor should be consulted if there is any indication of such an ear infection.

TYPES OF BEHAVIOR

You are probably aware that you perform a variety of acts that are partly or wholly involuntary. When you accidentally touch a hot surface, for in-

stance, you promptly jerk your hand away, and you do this before you realize that you have been burned. Such a response is called a *reflex act.* It is produced by a group of cells that make up one or more ***reflex arcs.***

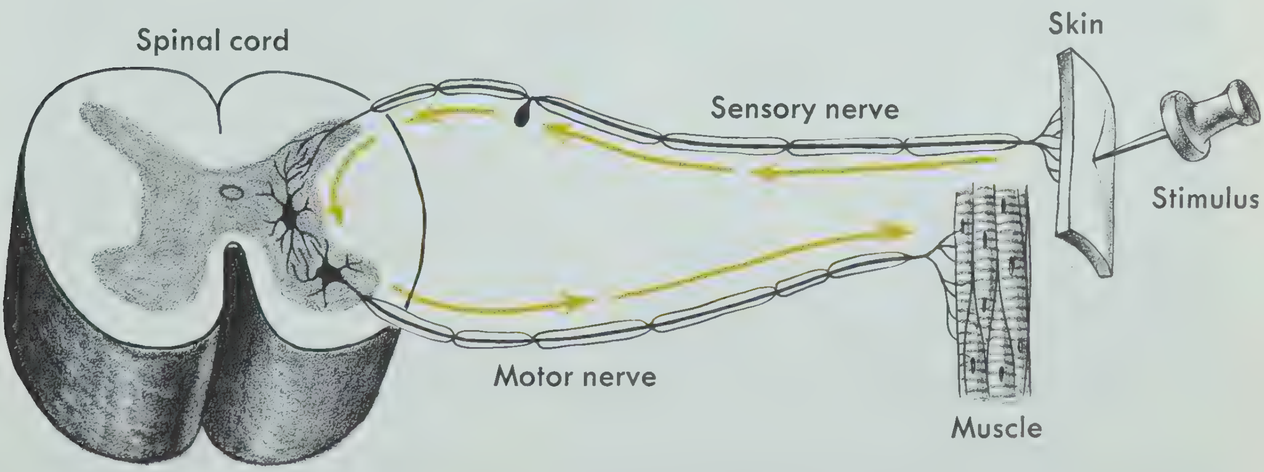
The reflex mechanism. We have many reflex arcs within our bodies, and they control a host of automatic or unconscious acts. A simplified diagram of a reflex arc is shown in Fig. 15–11. When a pin pricks the skin and stimulates a nerve cell, the cell sends a message along its axon to cells of the spinal cord. Now a cell in the spinal cord sends out a message along its axon to the cells of a muscle. The muscle cells contract, and the skin is jerked away from the pinpoint.

Actually, most human reflex arcs are not as simple as the one shown in Fig. 15–11. A message coming into the spinal cord would stimulate not one, but a number of cell bodies in the cord. Messages would go out to the muscles through a number of axons. Meanwhile, some of the cell bodies in the spinal cord would relay the message along fibers that lead to the brain. You would then become aware that the pin had pricked your skin and you would feel pain. You would be able to decide whether you wanted to modify or control the response you had made. But this would come *after* your first reaction had taken place.

One of the first things you learn about reflex acts is that some of them can be modified, if you wish to do so. Other reflex acts, including many that involve the internal organs, are purely automatic or involuntary. You cannot control reflex acts of this type. No doubt, reflex acts are very useful, because if the brain had to consciously direct such functions as breathing, digesting, and excreting wastes, it might be too overworked to do any remembering or thinking.

What are habits? Habits are acts that have been repeated so often that they have become largely or wholly *automatic.* Most of them are fairly complex patterns of behavior that you have learned to carry out in certain ways.

For example, you learn to throw a ball. At first, you are a bit awkward, and you have to think about what you are doing. After long practice, the habit becomes established, and you are much more assured about your throwing ability. But it is quite possible that you are



15–11. A simplified diagram of a reflex arc. Follow the path of the message from stimulus to response.

15–12. Is bicycle riding a habit? (*Lew Merrim from Monkmeyer*)

not throwing as well as you should. This is because your manner of throwing had faults at the outset, and you learned a "bad" habit. Now you have to start over, and develop a throwing habit that is more effective.

As you can easily guess, "good" habits are habits that work well. They make your general behavior more effective. You can have habits that relate to all sorts of acts, such as playing various games, catching fish with a rod and line, threading a needle, drawing a sketch, or brushing your teeth. Good habits tend to make many of the things you do partly automatic. Your mind is left free to deal with other problems.

Memory, intelligence, and knowledge. *Memory* is the ability to recall

15–13. Dolphins are known to be very intelligent animals. This bottlenose dolphin "reaches" for a mackerel while her trainer is busy sorting other fish. (*Marineland of the Pacific, Los Angeles*)

past experiences. It is the basic factor in *intelligence,* which is the capacity to learn, or to profit from experience. Various acts of cats, dogs, and other higher animals indicate that they remember past experiences, and profit from them. This ability is far better developed in man than in any other species.

Knowledge is the sum of what you know. It is what you can recall and use in everyday living. Suppose you are quite intelligent, but have never gone to school or learned to read. In this case, you probably have been denied a lot of useful knowledge. A person who is less intelligent, but has had good opportunities to learn, may have a good deal more knowledge than you do. In other words, it is not enough merely to be intelligent. You must *use* the intelligence to acquire knowledge.

EYE REFLEXES

In responding to changes in your environment, you often depend upon reflexes, including some more or less automatic acts. Such is the case when you walk. A complex group of reflexes involving your senses, nerves, nerve centers, and muscles are related to the act of walking.

Some other reflex acts are simpler, and easier to demonstrate. The following examples are reflexes that involve human eye structures. They belong to the group of reflex acts that you cannot control or modify at will.

RESPONSE OF THE IRIS TO LIGHT For this demonstration you need a partner to work with you. Seat him so that he faces a strong source of light. Have him cover his eyes with a handkerchief and his hand. Keep the eyes covered for one minute. At the end of this period, have him uncover his eyes.

Compare the size of the pupils with the size they were before the eyes were covered. This must be done very quickly. Then watch the pupils as they become larger. Ask your partner whether or not he can feel the irises responding to the presence of more light and whether or not he can prevent them from doing so.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What is the advantage of the automatic response of the iris to light? Explain.
2. Did your partner feel the change in his iris, as it responded to light? Can he control it in any way?

THE EYE-BLINK REFLEX Employ a partner as in the preceding case. Seat your partner facing you. Have him look straight at you so that you can watch his eyes closely. Without telling him when you are going to do it, clap your hands together a few inches in front of his face.

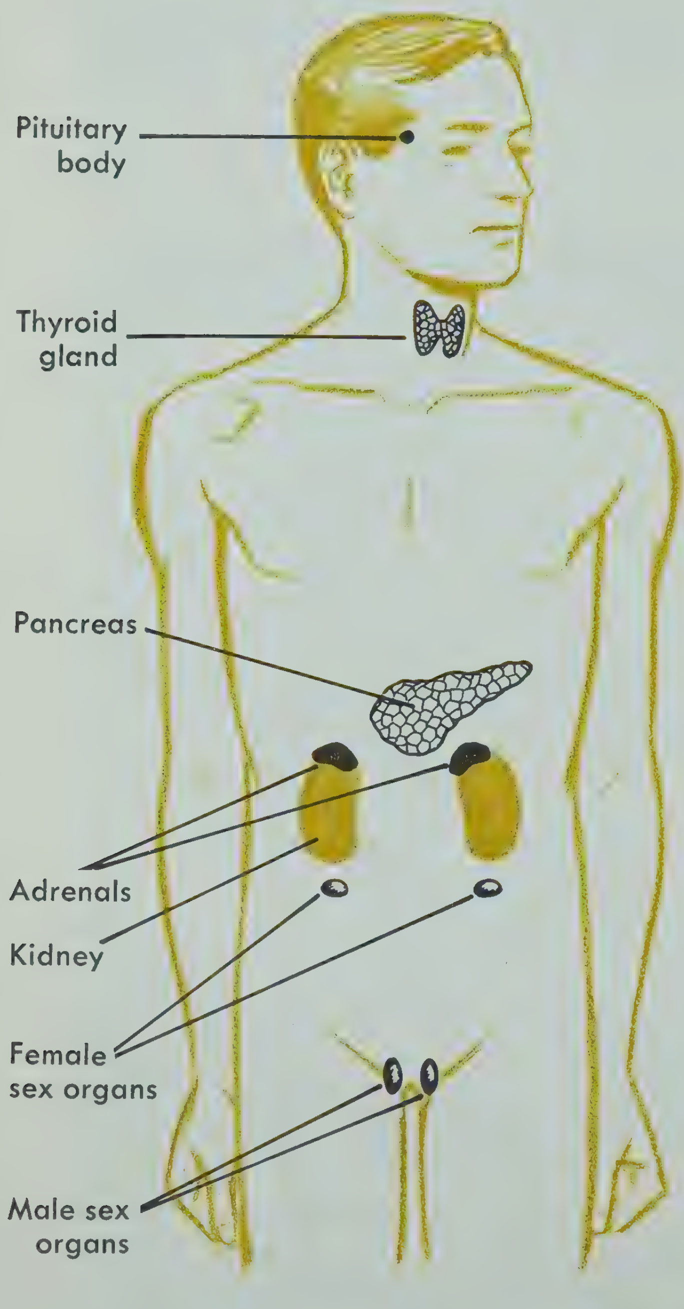
Watch your partner's eyelids. Ask him to see if he can prevent this response. Test him several times.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Why do you think the eye-blink is called a reflex?
2. Was your partner able to prevent the response? Explain.
3. What advantage appears to be gained by this reflex?

THE DUCTLESS GLANDS

You have learned that hormones are secreted by a number of ductless glands, and discharged directly into the bloodstream. They they are carried by the blood to the body tissues, where they bring about various responses in the cells. Hormones have been called "chemical messengers," because, like nerve impulses, they bring about responses. The control exercised by the hormones, however, is not the rapid type of control produced by motor nerve cells. Locations of some of the ductless glands are shown in Fig. 15–14.



15–14. Location of the ductless glands.

Insulin from cells of the pancreas. The pancreas is usually thought of as being a digestive gland, but in it are some special groups of cells that produce a hormone rather than a digestive fluid. This hormone is called ***insulin*** (*in*-suh-lun). Insulin is discharged into the blood stream by the cells that produce it.

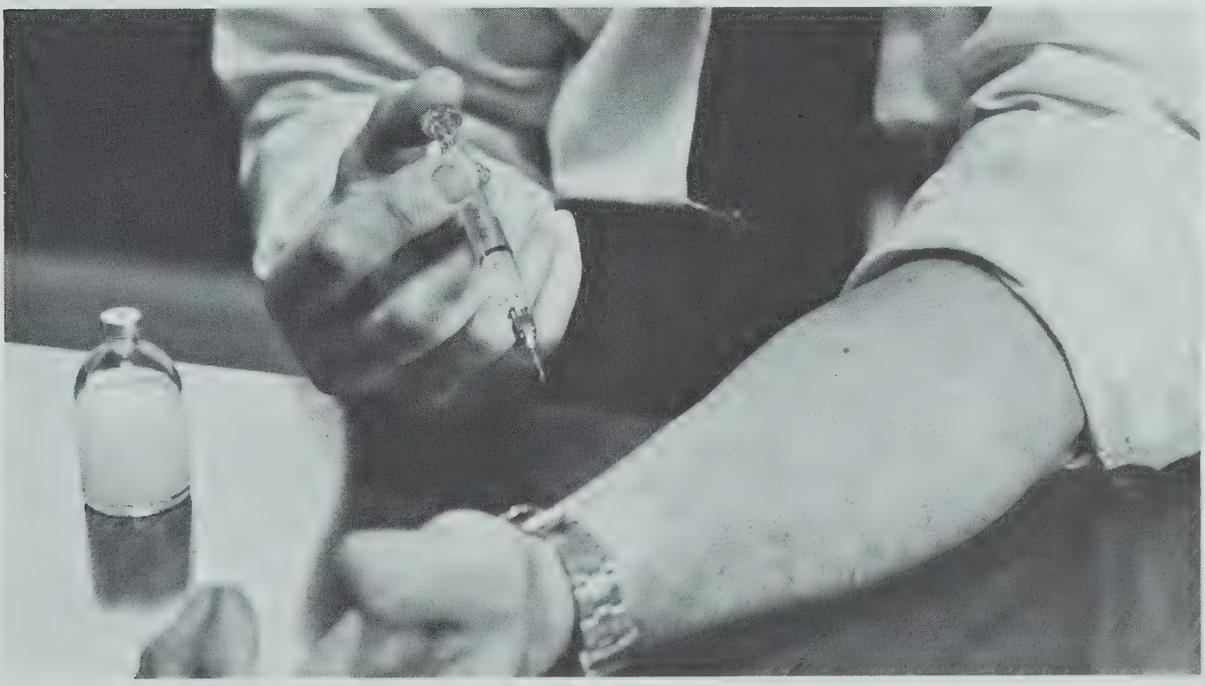
If a normal amount of insulin is not supplied by the pancreas, the disease known as ***diabetes*** (*dy*-uh-*bee*-tez) develops. The body fails to use its supplies of simple sugar properly, and excessive amounts of sugar collect in the blood. The kidneys begin to remove this sugar, which now appears in the urine. Meanwhile the body also fails to break down fats completely, when they are used to supply energy. Poisonous acid products are formed from the fats, and if enough of them accumulate, death may result.

It is possible, however, to keep diabetes well controlled by giving its victims the proper doses of commercial insulin. It is necessary to provide just enough insulin to bring the blood content of this hormone to a normal level. The amount needed varies, depending upon the extent to which the pancreas cells are failing to produce the hormone. But when proper doses are provided, the body is able to use simple sugar again, fats are oxidized in a normal way, so that poisonous end-products are not formed, and the condition is corrected. A special diet may also be established to reduce the amount of insulin required.

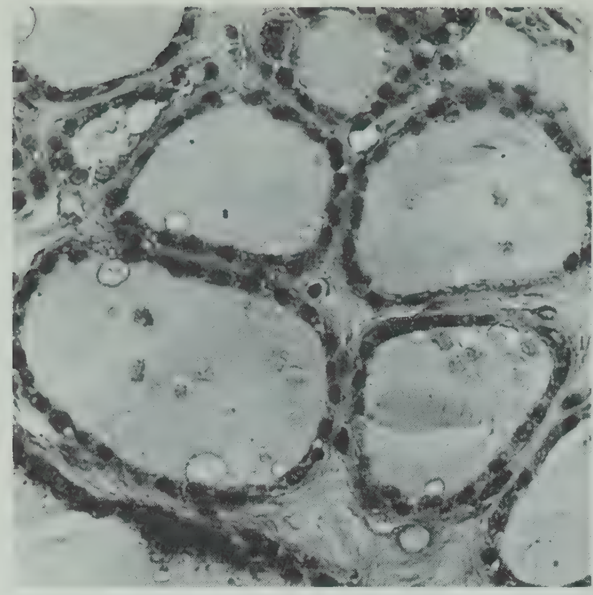
15–15. Camp Nyda at Burlingham, N.Y., annually provides 350 diabetic children with a month of camping fun and training in diabetes control. (*Photograph of Camp Nyda by courtesy of the New York Diabetes Association*)

Thyroxin from the thyroid gland. The ***thyroid gland*** is a two-lobed structure lying along the lower side of the larynx in the neck region. It secretes a hormone called ***thyroxin*** (thigh-*rocks*-sun), which controls the rate of *oxidation* in body cells. Too much thyroxin produces an abnormally *high* rate of oxidation. Too little thyroxin results in an abnormally *low* rate of oxidation.

One odd fact about thyroid tissue is that it contains a lot of *iodine*, and so does thyroxin. Years ago, it was noted that people living in some parts of the world were likely to develop a condition called ***simple goiter*** (*goy*-ter). In this condition, the thyroid gland enlarges to form a lumplike growth. Later, it was found that many of the people, who had simple goiter, lived in places where there was little iodine in the soil and water. Apparently their thyroid glands responded to the lack of iodine by growing larger. In such areas, iodine is now added to the diet in substances like common table salt.



15–16. A diabetes patient injects himself with insulin. (*Russ Kinne from Photo Researchers*)



15–17. A photograph of human thyroid tissue. (*Walter Dawn*)

People who have too little thyroxin in their systems tend to become fat, and are slow in their reactions. If this condition exists early in life, stunted growth, bowed legs, and even feeblemindedness may result. These effects are due to the fact that oxidation in body cells goes on at a less than normal rate. The modern remedy is to supply such people with the added thyroxin their bodies require.

On the other hand, adults whose thyroid glands are *overactive* are likely to be irritable, eat a lot of food, but lose weight, sleep poorly, and perhaps even develop a condition in which the eyeballs protrude. The remedy in this case

15–18. Two square-lipped rhinos fighting. Under emergency conditions adrenalin prepares the body for "fight or flight." (*Marc and Evelyne Bernheim from Rapho-Guillumette Pictures*)

15–19. An excess of the pituitary growth hormone in early life tends to produce a "giant." The man in this picture measures eight feet and seven inches tall and weighs 450 pounds. (*United Press International, Inc.*)

is to remove a portion of the thyroid gland, so that the production of thyroxin will be *reduced*.

Hormones of the adrenal glands. The two ***adrenal*** (ad-*ree*-n'l) glands form caps over the upper ends of the kidneys. Each gland has an outer layer and a separate central mass. The hormone produced by cells of the central mass is called ***adrenalin*** (*ad*-ren-*uh*-lin). Apparently, adrenalin serves to maintain a proper state of contraction in smooth muscle tissues, such as the smooth muscles in the walls of blood vessels. When this hormone is released into the body, the heart beats more rapidly, and smooth muscles in the walls of certain blood vessels contract. Digestion is slowed down temporarily, and muscular activity is favored. These responses prepare the body for emergency activity.

Cells in the outer portion of an adrenal gland produce a number of hormones. These hormones have various effects on the sex organs, the kidneys, the rate of oxidation in the body, the use of carbohydrate and protein foods, and the amount of water and salt in the blood. When these hormones are not produced in sufficient amounts, the victim loses his appetite, becomes weaker, and finally dies. This result, however, can often be averted by supplying the needed hormones from outside sources.

Other glands and their hormones. There are various other ductless glands in the human body. One of them, known as the ***pituitary*** (puh-*two*-uh-*tary*) ***body***, is attached to the underside of the brain. This gland has two main lobes, and produces a number of hormones. One hormone, in particular, is interesting because it is related to the production of giants and dwarfs.

When this growth hormone is *overabundant* in early life, it appears that the unusually large body of the so-called "giant" may be the result. On the other hand, *lack* of this hormone in early life apparently leads to the production of the undersized "dwarf."

Other hormones are secreted by the male and female sex organs. These ***sex hormones*** have effects upon development of the secondary sex characteristics, which appear before or during adolescence. This period of develop-

ment is called ***puberty*** (*pu*-ber-tee). During puberty a boy's voice "cracks" and then deepens. A beard appears and there is an increase in body hair. A young girl's breasts develop, fat deposits under the skin are formed, and menstruation begins. There are also many mental and emotional changes during the period of puberty.

A group of four small glands, called the parathyroids, lie close to the thyroid gland in the neck region. The hormone that they secrete affects the amount of calcium salts in blood, bone, and tooth formation, and the activities of muscle tissues.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. cerebellum	Structure that stretches across the entrance to the middle ear.
2. cochlea	Hormone produced by cells in the pancreas.
3. cornea	Light sensitive layer in the eye.
4. eardrum	Hearing center whose cells connect with the brain.
5. insulin	Hormone that controls the rate of oxidation in body cells.
6. nerve	Brain center responsible for body balance.
7. retina	Bundle of axons and connective tissue.
8. thyroxin	Transparent covering in front of the eye.

B

1. cerebrum	Eye part that changes shape to focus image on the retina.
2. diabetes	Source of hormone related to the growth of giants.
3. eustachian tube	Structure responsible for regulating air pressure in the ear.
4. iris	Disease in which body fails to use its sugar supplies properly.
5. lens	Carries messages away from the nerve cell body.
6. axon	Highest control center of the brain.
7. pituitary body	Ear structures involved in maintaining balance.
8. semicircular canals	Part that controls the amount of light entering the eye.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Stomach cells secreting gastric juice in response to the presence of food, provide an example of an involuntary act.
2. Although breathing is basically involuntary, it can be modified by conscious control.
3. Nerve cells have cytoplasm but lack nuclei.
4. A nerve cell receives incoming messages on threadlike projections called dendrites.
5. Some nerve cells have nerve fibers that are two to three feet long.
6. A nerve message can be conducted along a motor nerve fiber in either direction.
7. Nerves are made up entirely of nerve fibers or axons.
8. Nerve messages from motor nerve cells control the actions of muscles.
9. The cerebellum is the memory center of the human brain.
10. Conscious acts, such as speaking and singing, are controlled by the medulla of the brain.
11. The nerves, that enable us to see, hear, and taste, connect directly with the brain.
12. When damaged, nerve tissue is less likely to repair itself than other body tissues.
13. The pupil of the eye is really an opening through which light enters the eye.
14. The colored part of the eye functions to focus images on the retina.
15. Nearsightedness is caused by an abnormal shape of the eyeball.
16. Vibrations of the eardrum are carried to the sensitive part of the ear by the eustachian tube.
17. The hearing center of the inner ear is a gas-filled structure.
18. Microorganisms may reach the ear through the blood.
19. When you feel too warm and decide to move to a cooler place, the act is called a reflex.
20. A habit is a learned act that has become largely or wholly automatic.
21. If a person has great intelligence he must also have a great deal of knowledge.
22. Hormone controls and nerve controls act at about the same rate of speed.
23. Ductless glands discharge their secretions into the blood stream.
24. Diabetes is due to a diseased thyroid gland.
25. A person with an overactive thyroid gland may be treated by removal of part of the gland.

26. The adrenal glands are located close to the kidneys.
27. A giant is likely to be the result of an underactive pituitary gland.
28. A group of four small glands located near the thyroid gland are responsible for the development of secondary sex characteristics.

DISCUSSION QUESTIONS

1. List several ways in which your body responds to factors in its surroundings.
2. List several ways in which your body responds to internal factors. Give important details.
3. Distinguish between voluntary and involuntary acts. Give examples, and explain the body parts involved in each case.
4. Describe a nerve cell or neuron. Explain how such a cell is related to a nerve.
5. Explain how nerves and muscles act together to bring about movements of body parts.
6. Describe the human brain, and the functions of its parts.
7. Why is it that damage to the backbone and spinal cord sometimes results in paralyzed leg muscles?
8. In what ways may polio viruses affect the body? How may such effects be overcome?
9. Explain how a blow on the head may affect many other body parts.
10. Describe the eye and the functions of its parts.
11. Why are some people nearsighted, while others are farsighted? Explain in detail.
12. Describe the ear and the functions of its parts.
13. What factors may cause damage to the ear and hearing? How can such damage be avoided?
14. Define a reflex act. Explain how such an act operates.
15. What are habits, and how are they established?
16. In what ways are some habits more effective than others?
17. Distinguish between intelligence and knowledge. How is memory related to each?
18. How is the action of a hormone similar to that of a nerve? How are the actions different?
19. What is diabetes and how is it treated?
20. Describe the glands in the throat and the functions of their hormones.
21. What diseases are associated with abnormal thyroid gland function? How are these conditions treated?
22. In what ways does adrenalin affect body parts?
23. How are hormones related to the growth of dwarfs and giants?

THINGS TO DO

1. Prepare a model of a motor neuron. Use a bit of clay to represent the cell body, and pieces of string or wire to represent the dendrites and the axon. Build other nerve cell models, and arrange them to show how a reflex arc operates. Be sure to label the cell parts and indicate the directions of the nerve impulses.
2. Using sketches or models, compare the brain structure of a fish, an amphibian, a reptile, a bird, and a mammal. Label the brain parts to illustrate the structures they have in common.
3. Find out how a camera works. Report your findings to the class and explain how the camera is similar to the eye, as well as different from the eye.
4. Invite your school nurse to speak to the class on care of the eyes and ears. Also ask her to discuss glasses and hearing aids.
5. Prepare a list of activities you perform each day by habit. Select one habit that you think you can improve. Outline a plan for yourself, and see if you can change the habit. Keep a record of what you do and the results.
6. Hormones act as "chemical messengers" in plants as well as in animals. Using reference books as a source of information, prepare a report on plant hormones or auxins. Include a section concerning how man makes use of auxins to promote flowering, growth of roots, fruit formation, and to control weeds.
7. Hormones of the pituitary gland have effects on several other glands. Using reference books as a source of information, prepare a diagram to show how pituitary hormones affect the thyroid gland and the adrenal glands.

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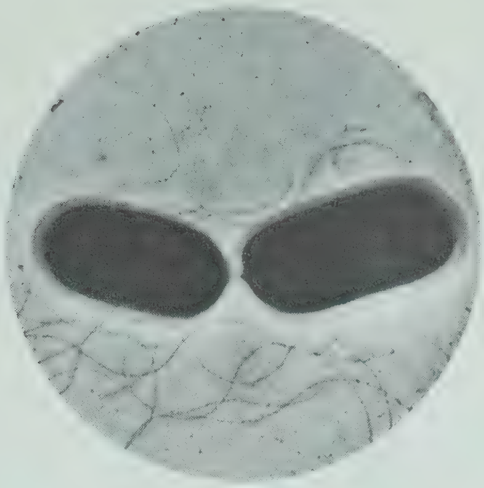


CHAPTER 16

The Control of Diseases

If you had lived in Europe three centuries ago, you probably would have been in constant fear of disease. For one thing, plague or the "black death" was claiming thousands of victims. Other common afflictions were various diseases of childhood. Malaria and smallpox took a daily toll. An average human life span was about 20 years.

The worst of this age-old problem was that no one really knew much about the cause or cure of diseases. Some people thought that evil men were putting poisons in the wells. Others believed that diseases were punishments for sins. It was only in the past century that tiny parasites were found to be responsible for such afflictions as plague and malaria.

Three centuries ago, you would not have found a dentist to treat an aching tooth. For any operation, you would have gone to a barber. Drugs used to "heal," might have included powdered Egyptian mummy, moss from the skull of a dead criminal, or burned materials obtained from toads and insects. One idea was that evil spirits lived in the body of a sick person, and could be "disgusted out" by using unpleasant medicines. The discovery of the modern drugs was still far in the future.

PARASITES AND DISEASES

On page 287, you read how Pasteur discovered that bacteria cause certain diseases. Other scientists were soon carrying out studies along similar lines. Before many years had passed, it was well known that a number of diseases were caused by microorganisms.

Microorganisms that cause diseases are called *germs*. Another word that means the same thing is ***microbe*** (*mi*-krob). Since they attack living animals and plants, and live at their hosts' expense, these microbes are parasites.

The nature of infection. When germs enter your body, it does not necessarily mean that you will become ill. In fact, you probably have some germs

16–1. Centuries ago, a barber doubled as a surgeon. (*National Library of Medicine, Bethesda, Maryland*)

in your body at the present moment, and so do all of your friends. In your body, many of these germs will not find a favorable environment for growth.

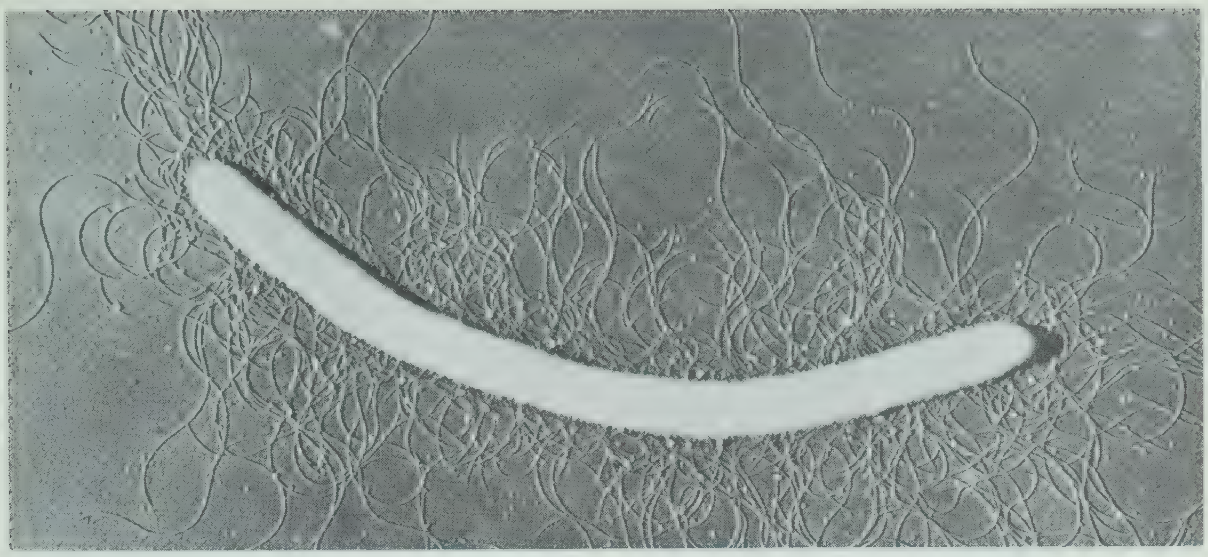
But now and then, germs get into human tissues where conditions do favor them. When this happens, the germs may prosper and become numerous. Soon there are enough germs to cause trouble. The victim begins to show the signs of disease and he has what is called an infection. This means that there are enough germs in some part of his body to produce the symptoms of disease. A number of infections and their causes are shown in the table on page 365.

Bacteria and diseases. Some well-known germs are bacteria. Various other bacteria do not cause diseases, and therefore are not germs. Among the bacteria are types that are ball-shaped in form, and are known as ***cocci*** (*kok*-eye). There are also rodlike forms or ***bacilli*** (buh-*sill*-eye), and spiral forms that are called ***spirilla*** (spy-*rill*-uh). These three general types of bacteria are shown in Fig. 16–2.

If you look at the table on page 365, you will see that such diseases as cholera, diphtheria, one type of dysentery, leprosy, plague, most types of pneumonia, scarlet fever, tuberculosis, and typhoid fever are all caused by bacteria. For example, cholera is caused by a spirillum, tuberculosis by a bacillus, and many types of pneumonia by cocci.

Protozoans and diseases. Small *protazoan parasites* also cause a variety of human diseases. A number of these protozoans are found largely in tropical

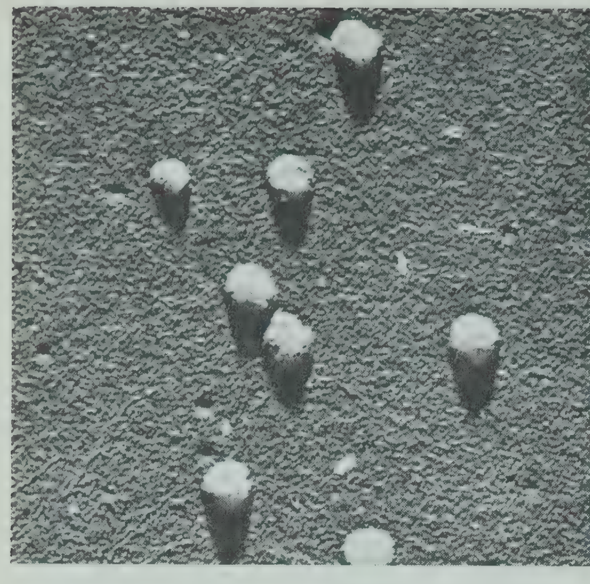
16–2. Three general types of bacteria.



16–3. This bacterium, *Proteus vulgaris*, has numerous flagella. As in the protozoa, flagella propel the bacterium through water and other fluids. (*Dr. James Hillier, R.C.A. Laboratories*)

SOME INFECTIONS AND THEIR CAUSES

Disease	Cause	Spread by
Chicken pox	Virus	Contact
Cholera	Bacterium	Food and drink
Common cold	Virus	Contact
Diphtheria	Bacterium	Contact
Dysentery	Bacterium	Food and drink
Dysentery	Protozoan	Food and drink
Fungus infections	Fungi	Contact
Influenza	Virus	Contact
Leprosy	Bacterium	Believed to be contact
Malaria (four types)	Four protozoans	Mosquitoes
Measles	Virus	Contact
Mumps	Virus	Contact
Plague	Bacterium	Fleas
Polio	Virus	Believed to be contact
Pneumonia	Over 30 types of bacteria	Contact
Pneumonia	Virus	Contact
Rabies (hydrophobia)	Virus	Bite of rabid animal
Scarlet fever	Bacterium	Contact
Smallpox	Virus	Contact
Tetanus	Bacterium	Wound contact
Throat infections	Various bacteria	Contact
Tuberculosis	Bacterium	Contact
Typhoid fever	Bacterium	Food and drink
Typhus fever (four types)	Protists	Lice, ticks, fleas, mites
Yellow fever	Virus	Mosquitoes
Whooping cough	Bacterium	Contact



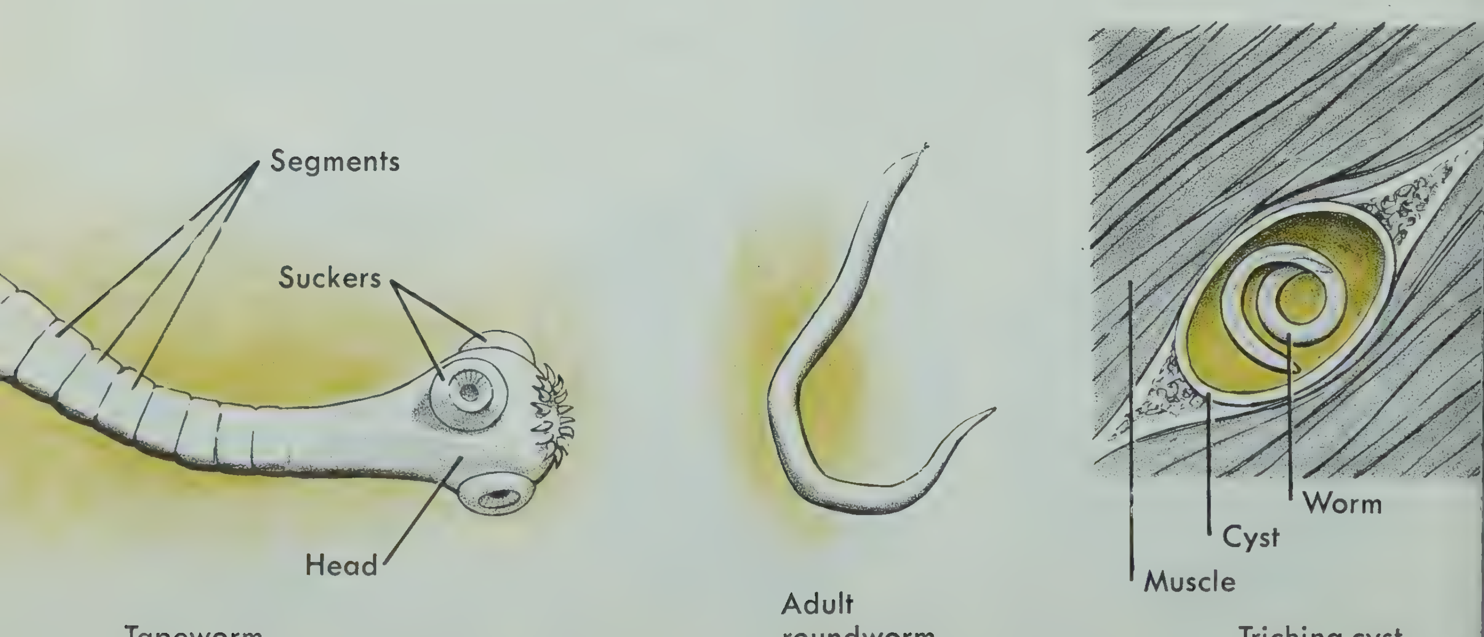
16–4. A photograph of the virus that causes influenza. (*Courtesy of R. C. Williams, Virus Laboratory, University of California, Berkeley*)

countries. But our own citizens are likely to be victims of one type of dysentery and one or more types of malaria, which also are protozoan diseases. We also must remember that in these days of airplane travel, many people visit warm areas and may be exposed to tropical diseases.

There are a number of protists that are human parasites. Some of them appear to be similar to the bacteria, and others are more like the protozoa. In the preceding table you can see that such protists cause a great many diseases including the four types of typhus fever, which once were great afflictions in times of war.

Viruses and diseases. As you read on page 98, viruses are composed of ultra-small particles. There is question as to whether viral particles are living things or just very active chemical substances. But at any rate, they lead active lives in the cells of their hosts, and are able to reproduce themselves, when in a favorable environment.

Viruses are responsible for many diseases, including chicken pox, common colds, influenza, measles, mumps, polio, one type of pneumonia, rabies, smallpox, and yellow fever. We usually consider these infections to be germ diseases, because they behave like the diseases caused by protozoa, bacteria, and other protists.



16–5. Three types of typical worm parasites.

SOME WORM PARASITES OF MAN

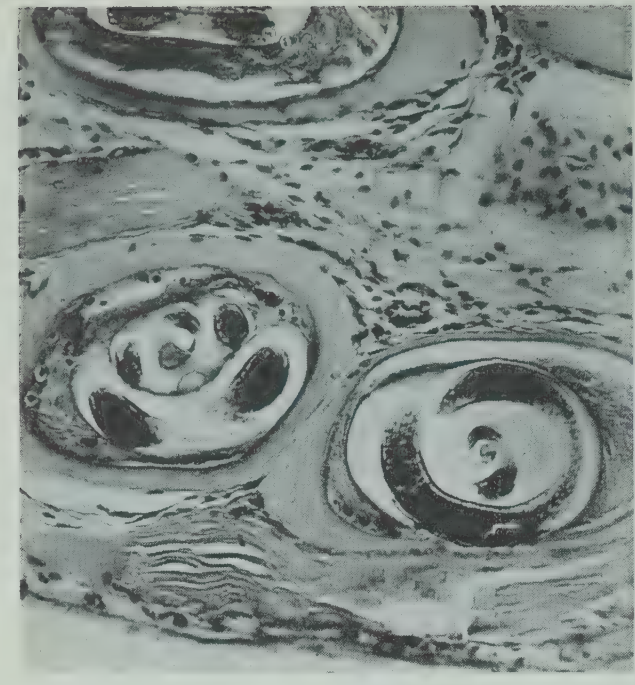
Name	Type of Worm	Known Hosts	Location in Human Body	Notes
Beef tapeworm	Flatworm	Man, bison, cattle, giraffes, llamas	Intestines (adult worm)	Requires two hosts to complete life cycle.
Pork tapeworm	Flatworm	Man, camels, dogs, monkeys, pigs	Intestines (adult worm); muscles (young worm)	Requires two hosts to complete life cycle. Young worm only rarely in man.
Eel worm	Roundworm	Man (related species in various animals)	Intestines, but may invade various body tissues	Requires only one host.
Trichina worm	Roundworm	Man, bears, dogs, foxes, pigs, rats, wolves	Intestines (adult worm); muscles (young worm)	Requires two hosts to complete life cycle.
Hookworms (two species)	Roundworms	Man	Intestines	Require only one host.

Infections caused by fungi. Certain *fungus* parasites cause a variety of human infections. One dangerous disease of the lungs, which is similar to tuberculosis in some of its symptoms, is caused by a fungus. In addition, a number of fungi are likely to form colonies in the skin layer. An example of the latter type is the fungus which causes the irritating condition known as "athletes' foot."

Worm parasites. People are also attacked by worm parasites, and a number of them can do serious damage to the human body. Some of these worms, such as the tapeworms and flukes, are flatworms (see page 91). Others are roundworms (see page 90). Among the tapeworms are types that are many feet in length, but some of the roundworm parasites are so small that they can only be seen by using a microscope. Fig. 16–5 is a diagram of some typical worm parasites.

Several of the common worm parasites found in temperate areas are listed in the preceding table. If you examine this table, you will see that the adult worms generally live in the human intestine. There are, however, certain exceptions, as in the cases of the pork tapeworm and the trichina worm. Both of these species must have *two different hosts* in order to complete their life cycles. These hosts, however, may be two individuals of the same species.

Let us take the trichina worm as an example. When young, this worm forms



16–6. Photograph of encysted trichina worm in muscle tissue. (*Walter Dawn*)

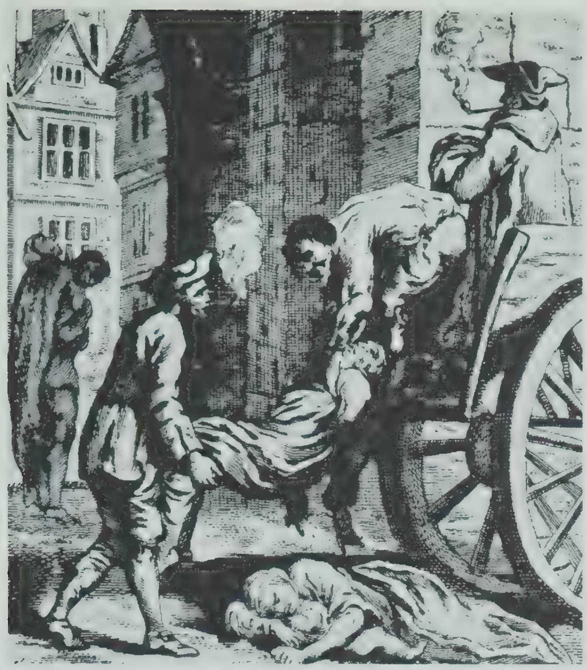
cysts in the *muscles* of both man and the pig, but as an adult its habitat is in the *intestines* of these hosts. The cysts containing the young worms are very small and may be present in large numbers. The main threat to man is *uncooked* or *partially* cooked pork that contains these parasites. Thorough cooking will kill them. When rare pork containing live worms is eaten, the parasites emerge from their cysts in the human stomach and intestine, and soon become adults.

The same thing happens when a pig eats garbage that contains pork scraps full of trichina cysts. The adult female worms, that develop in the digestive canals of both man and the pig, soon begin to bear young. These young worms bore out of the intestines and into the muscles, where they form cysts.

Adult worm parasites can be killed or driven out of the intestine by using drugs. But the young worms in their muscle cysts are not affected by drugs. Many people have gotten some trichina cysts into their muscle tissues. When a large number of these cysts are present, limbs may be partly paralyzed, and death may result. The practical way to avoid trichina worms, of course, is to be sure that pork products are well cooked before they are eaten.

Hookworms require only *one host.* Their adult females produce eggs in the human intestine, and the eggs pass out of the body with the solid wastes. The eggs hatch out on the ground surface. Then the young worms that come from them get into human hosts by boring through the skin. Usually this means the skin of bare feet, so the way to avoid hookworms is to wear shoes, when you are in areas where they exist. Proper sanitation also serves to protect people against hookworm parasites.

16–7. A very interesting photograph of a hookworm attached to the intestinal wall. (*Communicable Disease Center, Public Health Service, Atlanta, Georgia*)



16–8. This drawing shows persons suffering from the plague that swept over England in the mid-1600's. (*National Library of Medicine, Bethesda, Maryland*)

TRICHINA WORMS

If you have a slide bearing a section of pork muscle tissue that is full of trichina worm cysts, it is worthy of careful observation. First, examine the section with your unaided eye. See if you can detect the presence of any cysts among the pork muscle cells.

Now focus upon the section with the low power of a microscope. Move the slide about until you find a field that contains one or more cysts. The sectioning knife has passed through the cysts at various angles. Some of the cyst sections may be circular and some may be oval in outline.

Observe a cyst wall carefully. This type of cyst wall contains a deposit of *lime*. Within the cyst, you will see the remains of a young trichina worm. The worm assumes a spiral position within its cyst.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How numerous were the cysts in the section you examined? Why do you think their number might vary among specimens taken from different animals?
2. Do you think you could tell whether these cysts were in a piece of pork, if you examined it using only your unaided eyes? Give reasons for your answer.

HOW DISEASES ARE SPREAD

Diseases caused by germs are conveyed to us in a number of ways. Probably you have heard about ***epidemics*** (epa-*dem*-icks), in which many people have been attacked by the same disease at about the same time. Epidemics are not as common or widespread as they used to be, because we have much better defenses against some of them than we had 50 years ago.

But despite good defenses against some germs, they continue to exist. In some cases they live in human *carriers,* who have either had the disease or harbor the germs and are not made ill by their presence. In other cases, we "share" the germs with various domesticated and wild animals. About half of the germs that cause infections are known to live in the bodies of animals other than man.

Diseases spread by contact and near contact. A good many infections

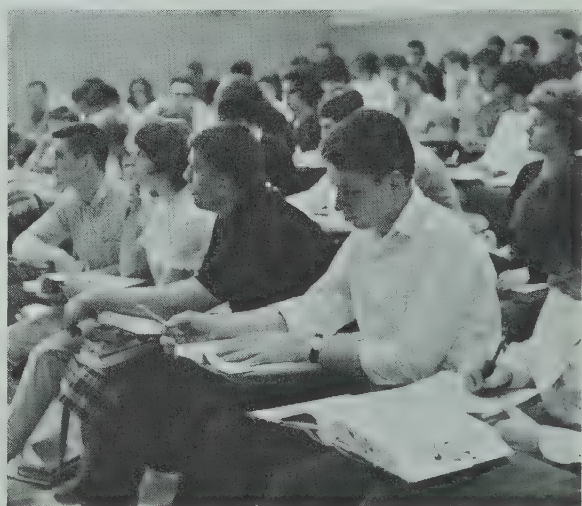
16–9. A photograph, taken at high speed, of a sneeze by a person with a head cold. (*Courtesy Dr. M. W. Jennison, Syracuse, University*)

are spread by contact or near contact. Consider, for example, the photograph shown in Fig. 16–9. When the man with the cold sneezes, a fine spray comes out of his mouth and nose for a distance of several feet. In this spray, there probably are viral particles that cause common colds. If you are in the path of the spray you are very likely to take some of these viral particles into your own breathing apparatus.

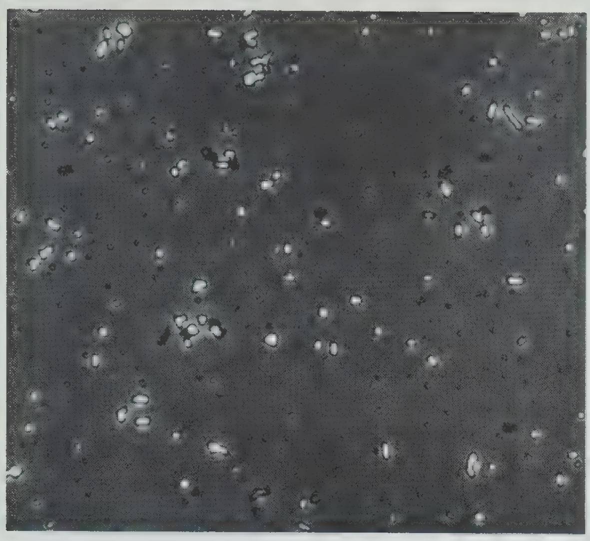
Other parasites can "ride" on the droplets of moisture in nasal spray, in the same way that viral particles seem to do. Of course, some germs do not live long outside the body of a host. But others are likely to survive for some time. Whenever you pick up something, you probably pick up some germs with it. Wherever you go, you leave some germs behind you.

The fact is, you have lived all your life in an environment that contains a multitude of germs. You have continued to live in spite of the germs, because your body has various defenses. There is no community in which you would be free from these small parasites. They are a normal part of every population.

Look at the table on page 365 again. In it, you see that such childhood dis-



16–10. Disease can spread very rapidly in a crowded classroom. (*Hays from Monkmeyer*)



16–11. *Salmonella,* a type of bacterium that causes food poisoning. (*Walter Dawn*)

eases as chicken pox, diphtheria, measles, mumps, scarlet fever, and whooping cough are all conveyed from person to person by *contact* or *near contact*. Being close to people, who have active cases of such diseases, is likely to result in getting some of the parasites from them.

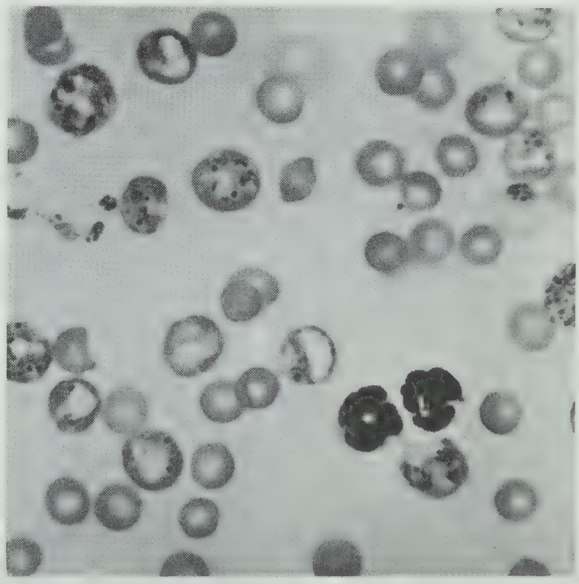
Diseases from contaminated food and water. Various parasites can remain alive in food or in water. When food or water contains such parasites, it is said to be *contaminated.* For instance, a number of disease-producing bacteria can live in certain foods. If we eat these foods, we develop cases of food poisoning. The bacterium which causes cholera, also is conveyed to us in contaminated food and drink.

Other similar cases include the bacteria and protozoa that cause the two general types of *dysentery*. Dysentery is a very common disease in some of the warmer countries. Wary travelers in such lands eat only food that has been cooked, and drink only bottled water, or water that has been boiled or chemically treated.

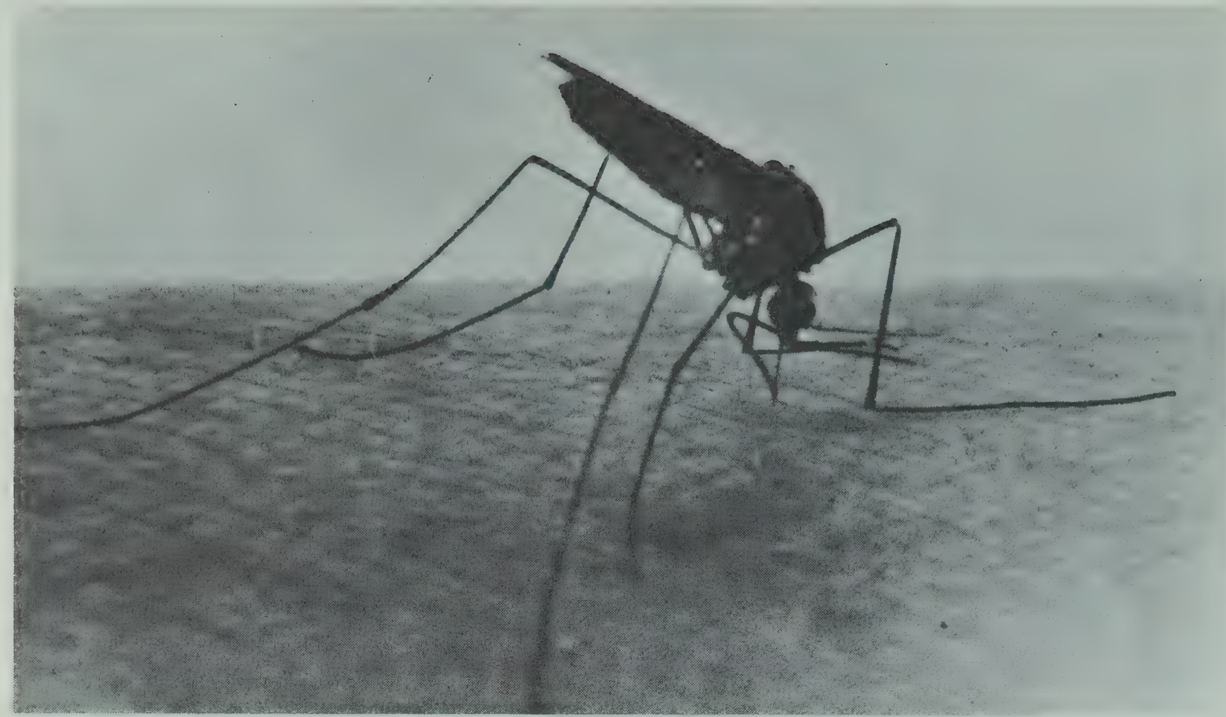
Typhoid fever is another feared disease that is conveyed to man in contaminated food and drink. Typhoid germs are known to linger in the bodies of some people for long periods of time. These people, like the notorious "Typhoid Mary," are carriers. If they handle foods, the foods are very likely to become contaminated. "Typhoid Mary" was a cook and over 50 cases of typhoid fever were traced to her. Carriers, until they are cured, must be prevented from coming in contact with food that will reach the public.

Insect and arachnid-borne diseases. A housefly prowling around the edge of a soup dish may very well bring some germs to the table. Such a fly is hairy, it usually is dirty, and the dirt on its body is likely to contain germs. A housefly carries these germs on the outside of its body in a purely mechanical way.

The case of malaria, which is conveyed to man by mosquitoes, is quite different. This is because the malaria parasites enter the bodies of mosquitoes, and pass through a part of their life cycles in the mosquitoes.



16–12. The malaria parasites. (*Walter Dawn*)



16–13. The female *Anopheles* mosquito carries the malaria parasites. Here, the mosquito is biting the arm of a man. (*USDA Photo*)

First, a mosquito bites a malaria victim, and sucks blood which contains malaria parasites. In the mosquito's stomach, the parasites pass through a cycle of reproduction, and produce vast numbers of small spores. After the spores have formed, the mosquito may bite another person and some of the spores are introduced into that person's blood. In human blood the spores enter red blood cells, grow, and again reproduce at regular intervals. The poisonous wastes they produce are responsible for the disease malaria.

Other diseases that are conveyed to man by insects include plague, which is carried by fleas, and yellow fever which is mosquito-borne. Two types of typhus fever are due to the bites of infected (a) lice, and (b) fleas. Two other types of typhus fever are due to the bites of infected (a) ticks, and (b) mites. Ticks and mites, of course, are arachnids rather than insects.

FLIES AND GERMS

Kill a housefly, and carefully remove a wing and leg from its body. Make a temporary mount of these structures on a microscope slide. See page 114. Examine your specimens under the low power of a microscope or a projector.

Note the jointed leg structure. This is something that all arthropods possess. Note also the many hairs and bristles on both the wing and the leg.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Where are the hairs located on the wing? The leg?
2. How do you think hairs may be related to the transportation of germs?

BODY DEFENSES

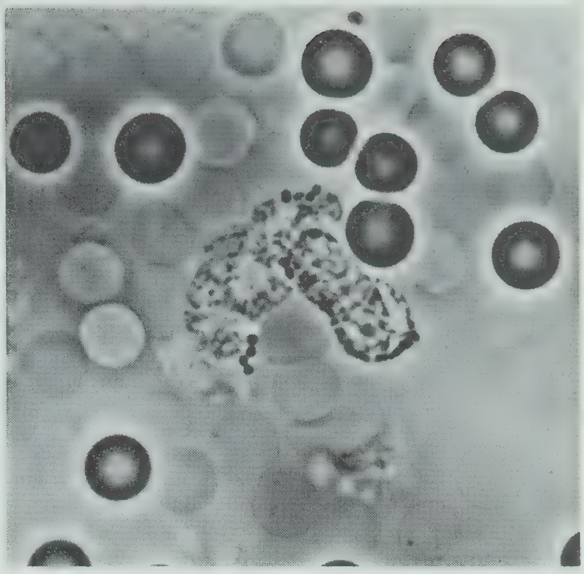
Your body has a number of *natural defenses* against germs. If this were not so, you would soon be overwhelmed by small parasitic invaders. For as you have learned, these tiny natural enemies are all around you throughout your life.

In a way, the human body is like a small community. You can always demonstrate that tiny organisms are present on its surface. Many more small organisms are always found in the digestive canal. Still other organisms are found in various body tissues. Fortunately, most of the organisms that collect in and upon the body, do no particular harm. In fact, some of them that live in the digestive canal may be useful. But there is always the possibility that some members of this population will be a threat to human health. This is why natural body defenses are very important to us.

The skin barrier. In earlier studies of the skin layer, you learned that it forms a protective covering for the body. Thousands of germs come in contact with the skin every day, but most of them do not penetrate this barrier. Some germs, however, can and do get into pores of the skin, and this is one reason why it is a good idea to keep the skin clean.

When certain germs become lodged in skin pores, infections may develop. There also are some germs and a few small worm parasites that can work their way through the skin layer. But for the most part, the skin provides considerable protection against the many parasites that collect on its surface.

Defenses in the digestive canal. It is, of course, easy enough for small parasites to enter the body by way of the mouth and the nasal passages. We swallow them along with food and drink, and they pass down into our stomachs. Here, some of the parasites are killed by an acid, which is a normal part of the gastric juice.

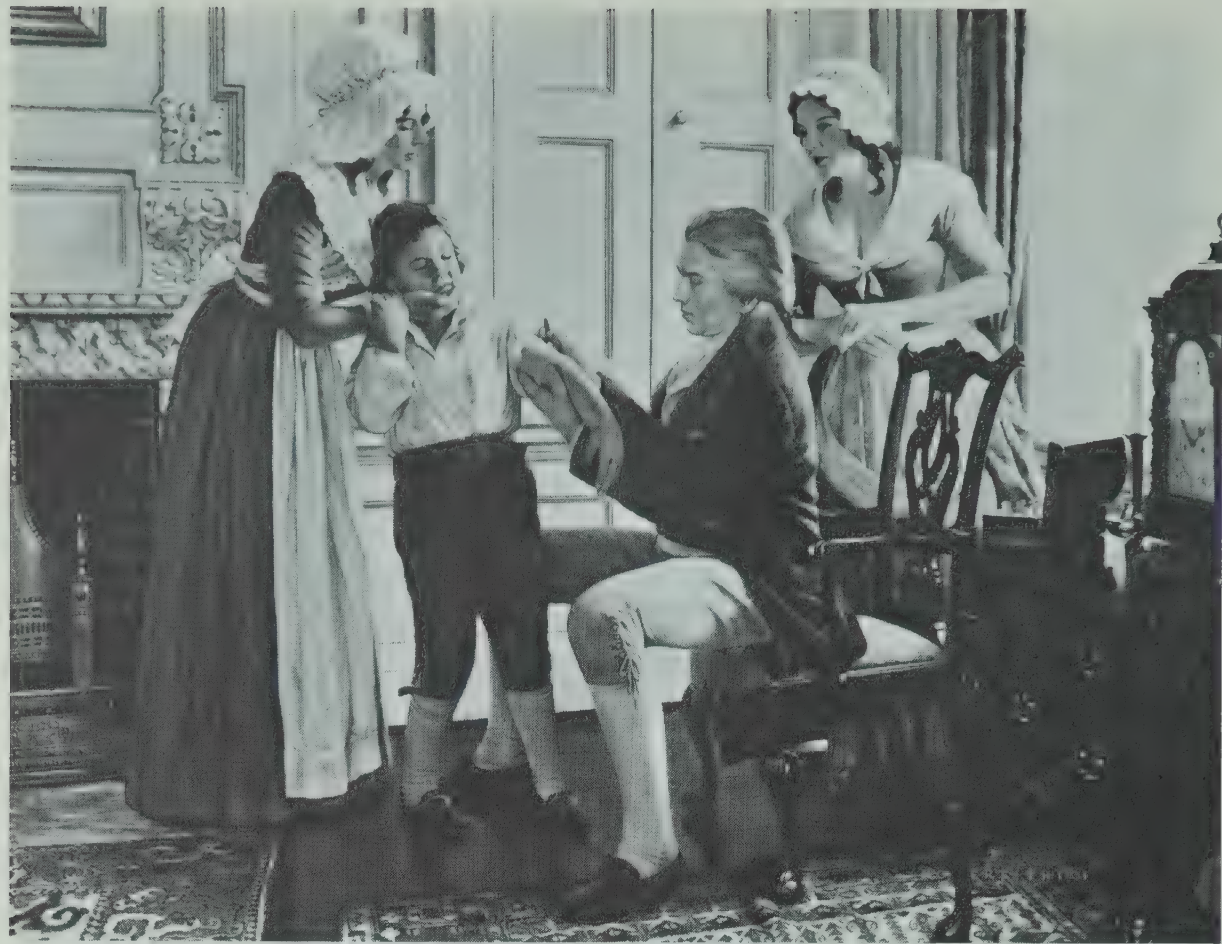


16–14. A white blood corpuscle engulfing bacteria. White blood cells are a major defense against harmful bacteria. (*Walter Dawn*)

These invading parasites must survive other trials that await them. For they must compete successfully with the tiny organisms that normally live in the intestines. Some of the new invaders probably fail in this competition.

Defenses of the blood and body tissues. Defenses, such as those previously described, prevent various infections. But some parasites do get into the blood and the tissues. Now they are likely to encounter white corpuscles, and some of the white corpuscles have the ability to destroy germs. Some tissue cells also have this germ-destroying capacity. White corpuscles tend to collect at any point in the body, where an infection is developing.

The blood also has a very important chemical type of defense. In the blood



16–15. A painting of Dr. Edward Jenner inoculating James Phipps. The young boy was Dr. Jenner's first patient. (© *1960, Parke, Davis, and Company*)

plasma are chemical substances called *antibodies.* Antibodies kill germs or render them harmless. But antibodies are *specific* in their actions. An antibody that protects against measles will not protect against yellow fever, and vice versa.

IMMUNITIES

Antibodies in blood plasma provide the protection that we call ***immunity*** (imm-*yoon*-uh-tee). You have often heard people say that they are immune to a certain desease. If they are right, their blood contains the antibodies which combat the germs of this disease.

We are born with some immunities, and we develop others. Some of these immunities are quite strong, which means that a person can be exposed to certain diseases, with little chance of developing active illnesses. Other immunities are only partial, which suggests that heavy exposure to the germs in question might result in active cases of the disease. While some immunities may last for months or years, others do not remain effective very long.

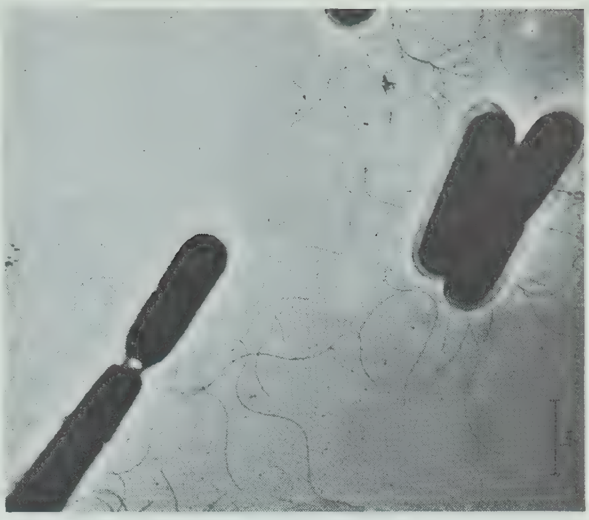
Immunity to smallpox. Your understanding of immunity will be better if you consider the history of smallpox. Smallpox was once a dreaded killer. The disease takes its name from the sores that develop on the skins of its victims. If they survive, the sores heal, but sometimes the skin of the face is left pitted with pox marks.

Smallpox has been a curse to mankind for centuries. Some Egyptian mummies bear the marks of this disease, and it was common among ancient populations in the Orient. In time, smallpox appeared in Europe, where it killed millions of people. Early explorers and colonists brought the disease to the Americas, where it proved fatal to many of the settlers and thousands of the native Indians.

Centuries ago, men in the Orient learned how to protect themselves against smallpox, although the method involved some risks. They took matter from a smallpox sore and introduced it under the skin of a nonimmune person. This person developed a case of smallpox in about a week's time, but it was usually a mild case, and the person was likely to be up and around again in two or three days. Thereafter, he was immune to the dreaded killer.

This Oriental practice spread to Europe in the eighteenth century, and then to the colonies of North America. It had one particularly bad feature: people treated with the smallpox materials developed mild, but true cases of smallpox. From them, other nonimmune people could and did contract dangerous cases of smallpox. But it was the best protection available at the time, and many of the men in General Washington's army were made immune to smallpox by this method.

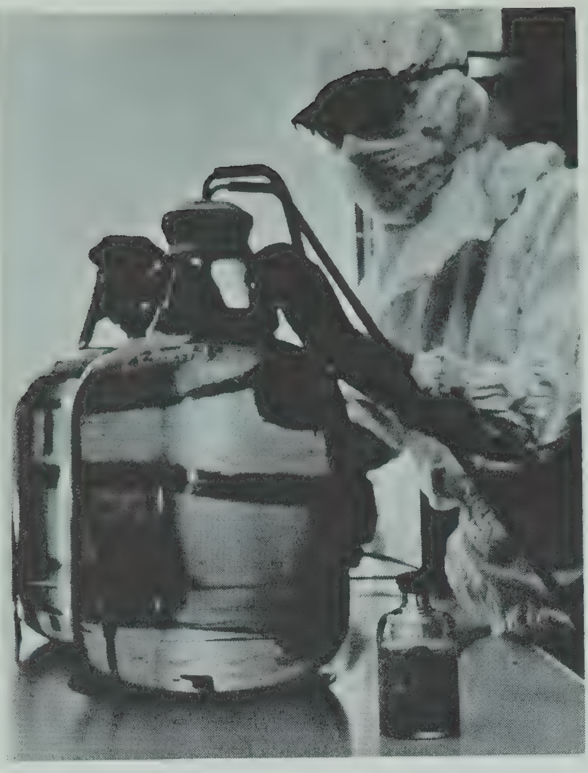
Near the end of the eighteenth century, an English doctor, Edward Jenner, developed a new method of making people immune to smallpox. Instead of inserting smallpox material under their skins, Dr. Jenner used material from *cowpox sores.* Cowpox is a disease of cattle that has little or no effect upon people. The cowpox material used by Dr. Jenner, however, made people immune to smallpox. The process was ***vaccination*** (*vak*-suh-*nay*-shun). The cowpox material used is the so-called ***vaccine*** (vak-*seen*). The Jenner type of vaccination is the one that is used today. It is much better than the older process, because people vaccinated with cowpox are no threat to the other people around them.



16–16. The bacteria which cause tetanus. (*Stuart Mudd and T. F. Anderson, Jour. Am. Med. Assn., 126: 632,1944*)

Active and passive immunity. Immunity depends upon the presence of antibodies in the blood plasma. When you contract a case of a disease, such as smallpox, your own blood develops these antibodies. Your blood does the same thing when you receive cowpox vaccine. In either case, the immunity developed is called *active immunity.*

Now let us consider the disease known as *tetanus* or "lockjaw." It is called "lockjaw," because the jaw muscles go into a state of rigid contraction as the disease progresses. Tetanus is caused by a bacterium that is anaerobic. It prospers in deep wounds of the puncture type, where it does not come in contact with the air. Tetanus is one of the main threats to health when a person receives such a wound.



16–17. This technician is adding measles virus to a tissue culture which will provide a medium for virus growth. The measles vaccine is made from the virus. (*Courtesy of Chas. Pfizer and Company, Inc.*)

Tetanus would be more common today, but for the fact that our defenses against it are good. In fact, the human body can be protected in advance by giving the individual an injection of tetanus vaccine. Tetanus vaccine consists of killed tetanus organisms that have been cultured in the laboratory. Having been killed, these organisms cannot multiply and produce an active case of tetanus. But when they enter the human blood, antibodies that act against them are produced. The individual becomes immune to tetanus. This is a case of active immunity.

But there is another way to protect people against tetanus. Tetanus vaccine is given to a laboratory animal, and antibodies against tetanus are built up in this animal's blood. Plasma from this blood contains the antibodies, and this substance can also be used to make people immune to tetanus. It probably would be used if the person treated had already begun to show signs of the disease. You can see that in this case the person's own blood does not develop the antibodies. This is an example of *passive immunity.*

Conferred immunities. Immunities that we acquire through the use of vaccines are *conferred immunities.* This is the "easy way" to become immune. It is, of course, possible to become immune by contracting active cases of various diseases, but this may be a threat to lasting health and even to survival. And remember that the antibodies, which make you immune to one disease, do not protect you against other diseases.

Conferred immunities can either be active immunities or passive immunities. In general, active immunities are more lasting than passive immunities. But eventually, even in the case of active immunities the protection tends to become less effective. This is why the so-called "booster shots" are sometimes given.

Conferred immunities protect people against diphtheria, rabies, smallpox, tetanus, and typhoid fever. Today there are vaccines for cholera, influenza, measles, plague, polio, scarlet fever, spotted fever, and yellow fever. There also are a number of experimental vaccines undergoing development and testing.

Since we are born with some antibodies and develop or receive others in the course of time, every person is more or less protected against some diseases. But this is a protection that varies from person to person. Thus, one person may be reasonably protected against dis-

eases A, B, D, F, and H. His friend is better able to withstand diseases C, E, and G, Moreover, both of them may develop some new immunities at any time. And some of the immunities they now possess may become weaker.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. "athlete's foot"
2. bacillus
3. carrier
4. cowpox
5. gastric juice
6. immunity
7. infection
8. mosquito
9. tapeworm
10. tetanus

Protection provided by antibodies.
A parasite that may grow to be many feet long.
Any condition caused by rapid increase of germs in body tissues.
Rod-shaped bacterium.
Disease from which material used in smallpox vaccine is obtained.
A disease caused by a fungus.
A person who is not ill, but who can pass disease germs to another person.
Organism that spreads malaria.
Acid-containing substance that helps protect the body against germs in the stomach area.
Disease caused by an anaerobic bacterium.

B

1. antibody
2. coccus
3. contaminated
4. epidemic
5. hookworm
6. malaria
7. parasite
8. vaccine
9. virus
10. white corpuscle

The smallest of the disease-causing parasites.
Body cell that has the ability to destroy germs.
Any organism that lives at the expense of another organism.
Word used to describe food or drink that contains germs.
Substance that stimulates the body tissues to produce antibodies.
Ball-shaped bacterium.
A parasite that lives part of its life on the soil surface.
Disease caused by protozoans that attack red blood cells.
Condition in which many people become ill with the same disease.
Chemical substance in blood plasma that acts against a particular germ.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Three hundred years ago, the average human life lasted about 20 years.
2. Although the cures were not available, the causes of plague and malaria have been known for over two hundred years.
3. It was once thought that a medicine would be likely to produce cures, if it was unpleasant to take.
4. Pasteur discovered that some diseases are caused by bacteria.
5. Microbes are small parasites that can cause diseases.
6. It is likely that the body of a healthy person contains no germs.
7. Diseases caused by protozoans are important only in tropical countries.
8. Borderline organisms, such as those causing typhus, can be classified as protists.
9. Virus-caused diseases are uncommon in this country.
10. Adult worm parasites commonly live in the intestines of their hosts.
11. Trichina worms are passed from one host to another by certain insects.
12. Trichina worms, present in cysts, are easily destroyed by the use of drugs.
13. Hookworm infestation can usually be avoided by wearing shoes.
14. Germs that cause diseases in man rarely live in the bodies of other animals.
15. Parasites are a normal part of every natural community.
16. Dysentery is a disease that can be prevented by eating only food that has been cooked, and drinking only water that has been specially treated.
17. It is possible for a person to carry the germs of thyhoid fever and not have the symptoms of the disease.
18. A mosquito will pass malaria parasites to the first person it bites.
19. Microorganisms are normally present on the skin and in the digestive canal of man.
20. Any break in the skin may provide an entrance for microbes.
21. The antibody that protects against measles is equally effective against yellow fever.
22. Smallpox was the first disease for which a vaccine was developed.
23. Tetanus vaccine contains killed tetanus organisms.
24. When a person develops immunity due to a vaccination, he is said to have passive immunity.
25. Passive immunities generally last longer than do active immunities.

DISCUSSION QUESTIONS

1. Three centuries ago, what kinds of things were thought to cause disease? How were diseases treated at that time?
2. What is an infection, and what causes it?
3. Explain how bacteria may be classified according to shape.
4. In what way does the airplane function in the spread of tropical diseases?
5. In what way does a virus behave like a living thing? Like a nonliving thing?
6. Describe the life cycle of a trichina worm.
7. How can tapeworms and trichina worms be avoided? How can hookworms be avoided?
8. In some areas, garbage is always cooked before it is fed to pigs. Explain how this practice might affect the spread of trichina worms.
9. In what ways can the presence of worm cysts in muscle tissues affect a host?
10. Why is it that epidemics are much less common today than they were some time ago?
11. By what ways are diseases spread from one person to another?
12. What is it about a housefly that makes it a likely organism to spread disease?
13. Describe the life cycle of a malaria parasite.
14. Explain what is meant by the statement, "The human body is like a small community."
15. How does the skin function as a defense against disease? The digestive system?
16. What are antibodies, and how do they function?
17. Explain how immunization aids in the defense against disease.
18. Distinguish between active and passive immunity.
19. Why it is that tetanus is commonly associated with deep puncture-type wounds?
20. Explain how a person can be protected against tetanus in advance. What can be done for a person who has begun to show signs of the disease?
21. Why is it that people vary in their immunities to diseases?

THINGS TO DO

1. Contact your local health department or the school nurse, and find out what health problems exist in your community. Also find out what is being done to solve these problems.

2. Make a collection of pictures of parasites that infect humans. Make another collection of organisms that carry germs. Label each picture, and explain how each organism affects its host, or how it is involved in the spread of disease. Also explain how the organism can be controlled.
3. Prepare a bulletin board display to illustrate the life cycle of one of the following parasites:
    - Tapeworms
    - Trichina worms
    - Hookworms
    - Malaria parasites
4. Using reference books as a source of information, prepare a report on one of the following topics:
    - Health problems of the Middle Ages
    - Viruses
    - Food poisoning
    - Immunization
    - Antibiotic drugs
5. Find out what vaccinations you have had, and the date you received each of them. Also find out how long each vaccination can be expected to provide protection.

READING FURTHER

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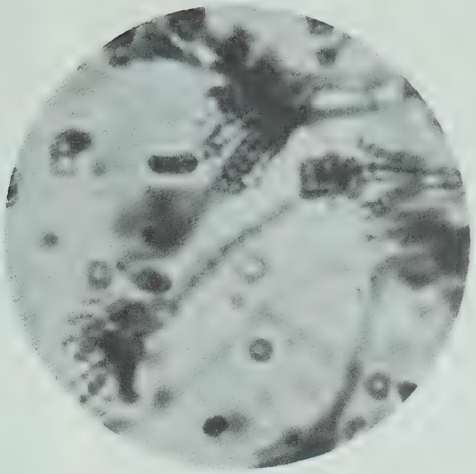
CHAPTER 17



The Public Health

The average person lives much longer today than he did a century ago. This is one reason why the human population is increasing so rapidly. In part, the longer life span is due to better nutrition, but modern drugs and other health safeguards can claim credit for most of the improvement.

Diseases such as measles, diphtheria, plague, and smallpox have become far less common in the modern world. We know what causes them, and we have strong defenses against them. The figures in the table, United States Annual Death Rate, reflect the great changes that have taken place in public health problems. A century ago, diseases like measles, scarlet fever, and whooping cough claimed many victims each year. Today, the major causes of death are heart and kidney diseases, together with various types of cancers.

But even in the case of diseases that can be well controlled, we have continuing problems. For example, people cease to fear a disease like smallpox, because there have been no outbreaks for a period of years. They do not always realize that this state comes about because many people have been vaccinated. So various members of the community fail to get vaccinated, usually because "it is just too much trouble." Then an outbreak of smallpox occurs. Now, many people can hardly wait to be vaccinated. But for some of them, the protection comes too late.

UNITED STATES ANNUAL DEATH RATE IN A RECENT YEAR

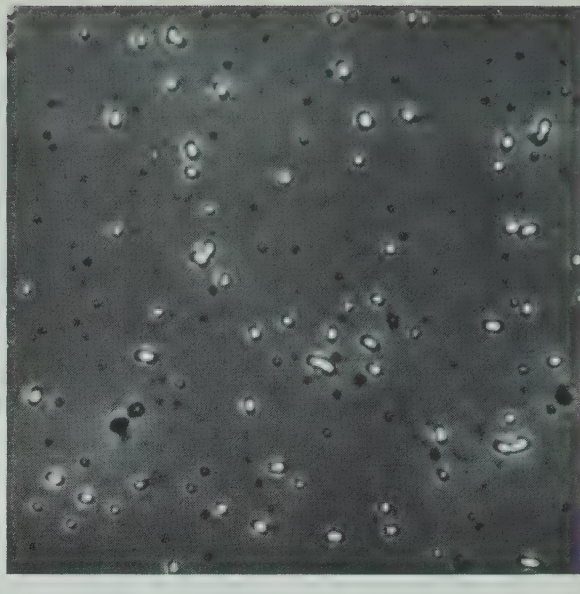
Cause	Deaths per 100,000 Population
Heart and kidney diseases	520
Cancers of various types	149
Accidents	53
Influenza and pneumonia	33
Liver disease (cirrhosis)	11
Tuberculosis	5
Measles	0.2
Whooping cough	0.1

We also have problems of maintaining pure food supplies, of garbage disposal, of water pollution, and of the control of insects and other animals that convey diseases to man. In all of these cases, the problems are closely related to the public health. In addition there are concerns about various heart diseases and cancer.

Some heart diseases are caused by parasites, as in the case of heart infections, but others may be *functional diseases.* Functional diseases are not due to the presence of parasites, although parasites may have done some damage to the impaired structures in the past. A functional disease is due to the inefficient working of some body part or parts. In the preceding table, you can see that functional diseases account for a large proportion of the deaths that occur today. In part, this is because more people are living long enough to develop these functional disorders.

PURE FOOD AND WATER SUPPLIES

The *Pure Food and Drug Act* became the law of the land in 1906, and has been strengthened periodically ever since. It maintains standards of purity for foods, and provides for the inspection of animals that are used as food. It also rules out the use of certain preservatives that might be harmful in canned, bottled, and dried foods. If a drug manufacturer produces a medicine that contains a habit-forming compound, this fact must be noted on the label. The manufacturer must not make false claims about drugs on the labels. Both food and drug producers must meet certain standards when they label their packaged products.



17–1. Paratyphoid organisms that cause food poisoning. (*Walter Dawn*)

Pure foods and milk. Food poisoning is due to the fact that foods have been contaminated with various types of germs. Careless handling accounts for the presence of some of these germs, even in foods that are quite fresh. Faulty canning of food products accounts for their presence in cans and jars. This may happen when foods are

17–2. The bacterium that causes botulism. (*Drs. S. Mudd and T. H. Anderson*)

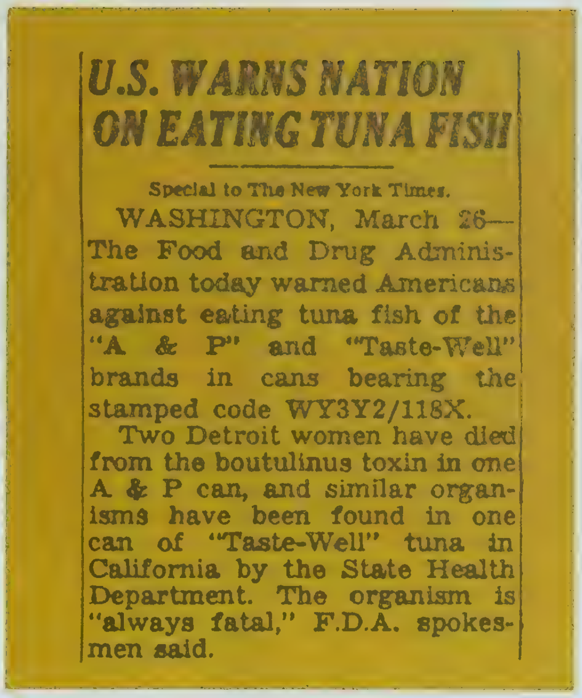
canned at home. Some of the germs that cause food poisoning can live and multiply in sealed containers, because they are anaerobic.

One common type of food poisoning is caused by bacteria that belong to a group of *paratyphoid organisms.* These bacteria get into foods, such as shellfish and milk, from the hands and bodies of human carriers. Houseflies can also carry the germs to foods that are in exposed places. Heating the foods to the boiling point will kill the germs, but if this is not done, people who eat the foods are very likely to become infected. Diarrhea, fever, and cramps are symptoms of this infection. Some attacks are rather mild, some make the victims very uncomfortable, and a few cause death.

Bacteria that live in foods may cause the proteins of meat and shellfish to undergo decay. ***Ptomaines*** (*toe*-mains) are compounds formed in this decay, and they produce another type of food poisoning when they are eaten. For this reason, it is wise to avoid eating decaying meats and shellfish.

By far the most dangerous type of food poisoning is ***botulism*** (*bott*-youlism). This is caused by a bacterium that sometimes gets included in canned or other preserved food. Within the cans, the bacteria multiply and form poisonous wastes. Often the ends of the cans become bulged outward, and their appearance gives a clear warning. The best thing to do with suspected food is to dispose of it safely. A single drop of the poison produced by this bacterium can cause death. It kills not only humans, but domesticated animals as well.

Milk supplies are often suspect, because they may have come from diseased cattle. This is why most of the milk we consume has been ***pasteurized*** (*pass*-teur-ized), or heated sufficiently to kill any dangerous germs it may contain. Dairy cattle are generally tested, and the diseased animals are disposed of. But it is always possible that an infected cow will escape detection.



U.S. WARNS NATION ON EATING TUNA FISH

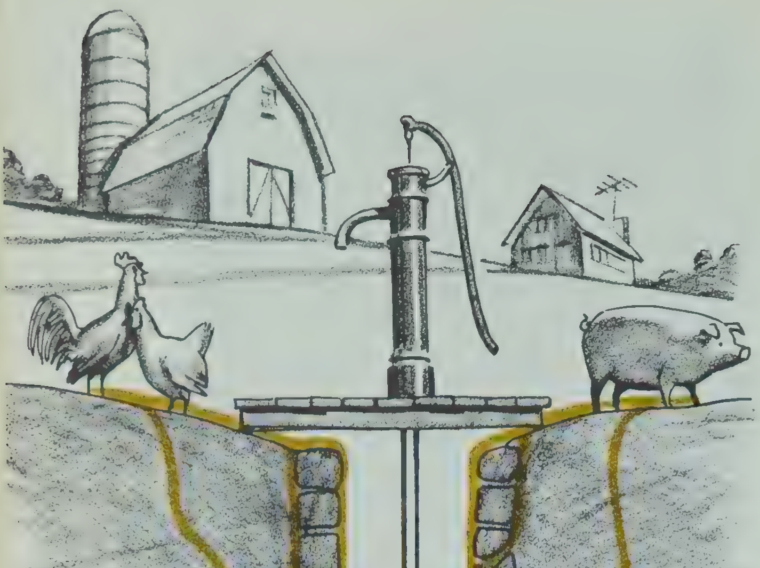
Special to The New York Times.

WASHINGTON, March 26—The Food and Drug Administration today warned Americans against eating tuna fish of the "A & P" and "Taste-Well" brands in cans bearing the stamped code WY3Y2/118X.

Two Detroit women have died from the boutulinus toxin in one A & P can, and similar organisms have been found in one can of "Taste-Well" tuna in California by the State Health Department. The organism is "always fatal," F.D.A. spokesmen said.

17–3. A recent article from the New York Times tells of botulism poisoning from canned tuna fish. (© *1963, by The New York Times Company. Reprinted by permission.*)

One cattle disease represented by the presence of germs in milk is tuberculosis. This is the bovine or cattle type of tuberculosis. The germs usually will not produce tuberculosis of the lungs in man, but they do produce tuberculosis in other human tissues. *Undulant fever* is a disease of cattle, goats, horses, and men. It is an unpleasant sort of infection that may last for weeks or even years. Protists cause undulant fever. You can get the disease by contact with diseased animals, and the protists which cause the disease appear in the milk of these animals.



17–4. This picture shows a water source which is likely to be contaminated.

You can see now why pure foods are so important in maintaining public health. In spite of careful safeguards, the possibility of food poisoning exists. After foods have been cooked and liquids have been pasteurized, they can be contaminated before anyone has a chance to eat them. The germs may be in the air, they may come from carriers, or they may be carried to the food by insects. This is why many communities have regular inspections of restaurants, food markets, bottling plants, and dairy farms. Even the containers that receive the foods may be contaminated.

Pure water supplies. Pure supplies of fresh water are essential to modern life. Whether the water comes from reservoirs, lakes, rivers, or wells, a number of safeguards must be observed. There are many ways in which waste products of man and other animals can get into water supplies. The stream which receives sewage from a city or town is an obvious example.

Another example of a water supply that is likely to be contaminated is shown in Fig. 17–4. Here the well that produces the water is near the barn. Wastes from farm animals can be drained down into this well, and in quantity if the well platform contains cracks and holes.

A city, which draws its water supplies from reservoirs, does not simply turn the water into the city water pipes. First, the water is filtered, and allowed to stand in settling tanks or basins. It may be sprayed up into the air to get rid of unpleasant tastes and odors. Single-celled algae in the water can cause such tastes and odors. Finally, a certain amount of chlorine may be

17–5. Aeration of water, one of the many ways of treating water. (*Annan Photo Features*)

added to the water to kill any germs that remain.

Water taken from a river may require rather special treatment. Such water is likely to contain a good deal of sediment, which can, of course, be settled and filtered out. But if the water has been contaminated by sewage from a town upstream, there may be a serious problem of making it safe to drink. You usually find that treated water from such a source contains a noticeable amount of chlorine.

17–6. Industrial pollution of the James River at Lynchburg, Virginia. (*U.S. Public Health Service, Division of Water Supply and Pollution Control*)

MICROORGANISMS IN FOODS

One of the problems food producers have to deal with is decay. You must face this problem when you keep foods in your home for any length of time. As you know, decay is brought about largely through the activities of bacteria and fungi.

SOME OBSERVATIONS OF FOOD DECAY

To test the rate at which decay takes place under several conditions, place a spoonful of moist ground meat in each of six clean test tubes, under the following conditions:

Tube 1. Place untreated ground meat in this tube.

Tube 2. Mix a half spoonful of salt with the ground meat in this tube.

Tube 3. Mix a half spoonful of sugar with the ground meat in this tube.

Tube 4. Mix a half spoonful of any spice you have handy with the ground meat in this tube.

Tube 5. Cover the ground meat in this tube with vinegar.

Tube 6. Put ground meat that has been dried out in an oven in this tube.

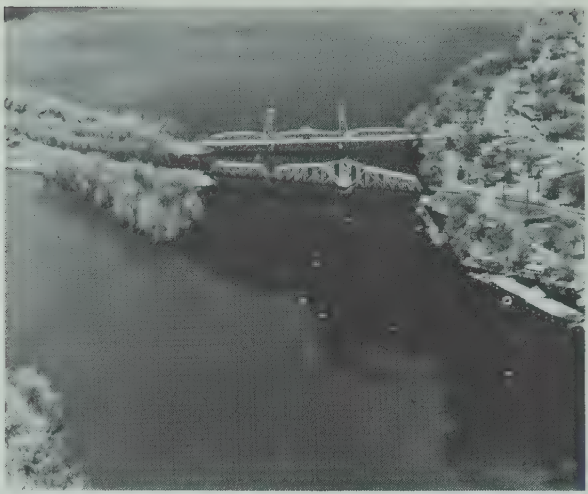
Now place cotton stoppers in all of the tubes, and leave them in a dimly lighted place at room temperature. Observe what happens for a period of days, and record the findings.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Which treatment seemed most effective in preventing decay? What is your evidence?
2. How do you think the organisms that produce decay got into the meat samples?
3. What other simple method could you use to preserve the meat?

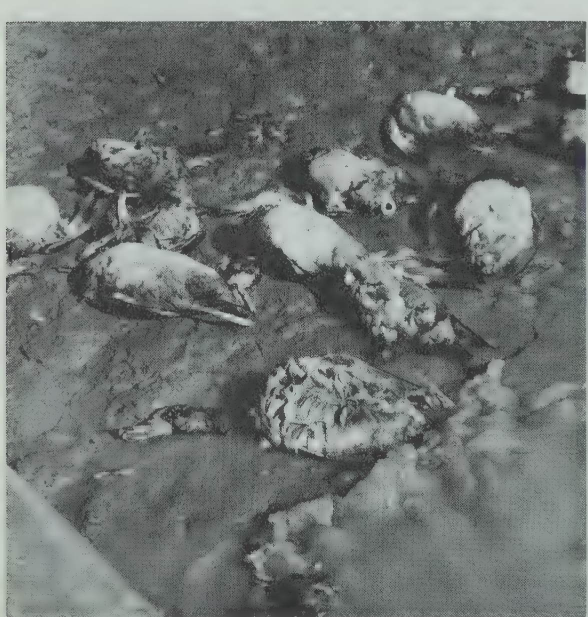
PROBLEMS OF SEWAGE AND GARBAGE

In the early days of settlement, towns sprang up along the rivers of North America. This was reasonable



17–7. Polluted water from the Mississippi being joined by water of the St. Croix River. Note the different shades of the two waters. (*Minnesota Conservation Commission*)

enough, because at the time, the rivers provided natural "highways" upon which people traveled by boat. Many of the new towns began to discharge their sewage into the rivers, because this was the easy way to get rid of it. This practice has been continued down to present times.



17–8. Ducks killed by oil polluted water. The oil prevents the birds from flying by weighing them down. (*Marvin Herder Jr. from Black Star*)

Sewage and stream pollution. Streams polluted by sewage are, of course, a menace to public health. All sorts of germs are likely to be present in sewage. After the water has flowed along a number of miles, most of the germs in it are dead, but before this happens, the contaminated water may cause trouble. To be sure, most people have better sense than to drink such water. But young people are likely to swim in the stream and as you know, swimmers often get water into their mouths. There also is the problem of the city downstream, which depends upon the river for its water supply.

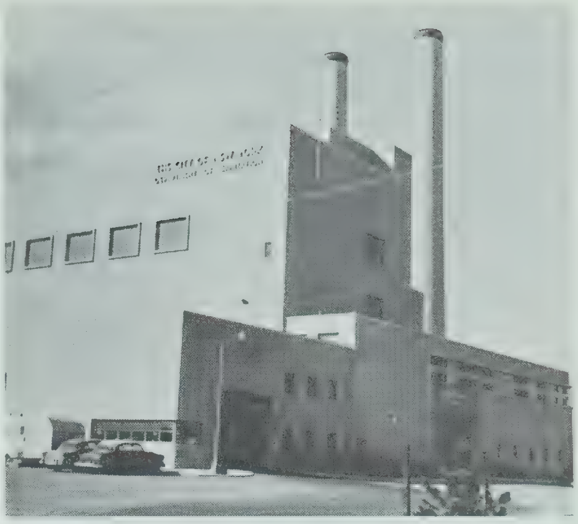
Add to this the fact that desirable wildlife in the polluted stream is destroyed, and you begin to realize why stream pollution acts against the public interest. If there was no other way to get rid of sewage, we would have little choice, but other and better ways are well known.

The community garbage and refuse dump. The community dump is another old institution that can easily become a nuisance. Sometimes junk and garbage are simply dumped on a vacant plot of land. No one burns or buries the mass of materials, which simply gets bigger and more ill-smelling as time goes on. A dump of this nature soon becomes a refuge and breeding place for rats, mice, and flies. These pests, in turn, are likely to spread germs far and wide.

Of course, a town dump does not need to be a pest hole. Refuse and garbage can be burned and buried, and not allowed to accumulate. But this requires regular attention and labor, which is not provided in some cases.

Disposal plants. The modern way to get rid of garbage and sewage is to "run" the materials through disposal

17–9. An unkept city dump is both unsanitary and unattractive. (*World Wide Photos*)



17–10. A modern garbage disposal plant. (*City of New York, Department of Sanitation*)

plants. In the waste materials are various useful chemical substances, which can be extracted. In some cases, the cost of operating the plants has been met by the sale of compounds recovered from the wastes. The remaining materials, that have no value, are made harmless before they leave the plants.

INSECT AND RODENT CONTROL

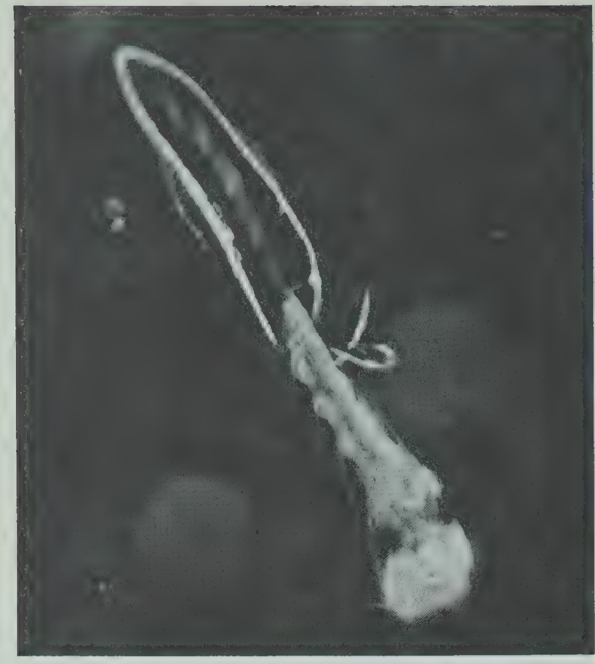
The biting, blood-sucking type of insect would be an annoying pest, even if it had no relationship to disease. The control of mosquitoes is especially important because some of them convey the diseases malaria and yellow fever to man.

The mosquito life cycle. In planning the control of mosquitoes, it is helpful to know something about their life cycles. Females of a well-known mosquito type lay their eggs in masses that float on the water of a pond. The eggs hatch to produce *larvae* that swim about in the water and seek food. After a brief period of growth, the larvae develop into *pupae,* which can move about, but do not take food. In fact, the pupae spend most of their time floating at the surface of the water. When *adults* have developed inside the pupal cases, these cases split open. The young adults emerge and rest on the floating pupal cases, while their wings dry and expand. Then they take to the air. These stages in a mosquito's life cycle are shown in Fig. 17–13.

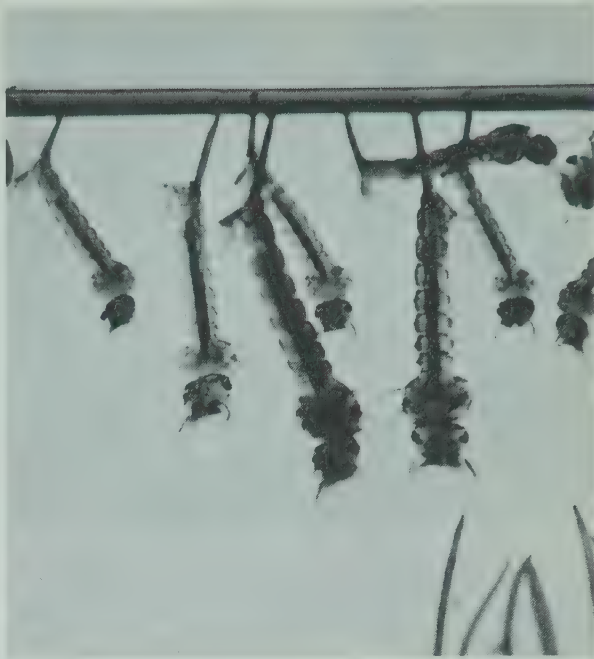
Only the *adult female* mosquitoes bite people and suck blood. But the males are an important part of the life cycle, for without them there would be no fertile eggs, and in time, no more mosquitoes.

Mosquito control problems. As you can see from study of the life cycle, mosquitoes must have quiet waters in which to develop. Swiftly running streams will not do, because the young adults are unable to perch on their pupal cases, while their wings dry and expand. But quiet ponds, sheltered lake shores, pools in marshes, and even old barrels and tin cans that are filled with water will serve as breeding places.

One way to get rid of these pests is to remove the waters in which they



17–11. A mosquito larva emerging from an egg. (*Struwe from Monkmeyer*)



17–12. Larvae of the *Culex* mosquito. (*Hugh Spencer*)

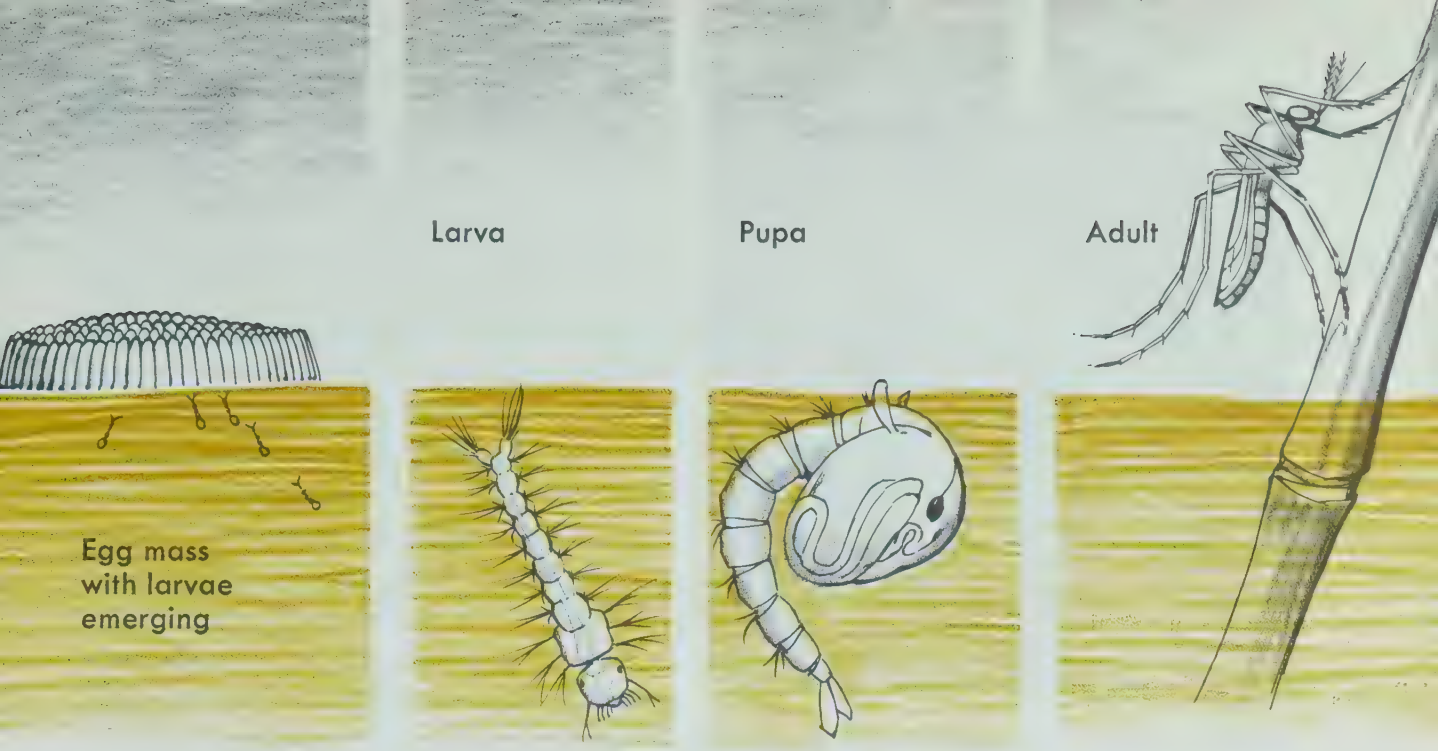
breed. This has been done effectively in various places. But it is not always the best solution for two good reasons. First, when marshes and ponds are drained in a farming country, the water table is very likely to drop to a low level. This, in turn, means less moisture near the soil surface and possible crop failures. Second, when you drain a marsh you must have drainage ditches. Rains wash sediments into these ditches, and the sediments block the ditches at various points. Soon there are many pools in the ditches and the mosquitoes begin to return. It is, of course, possible to reopen the ditches, but this requires more time and money.

Another way to control mosquitoes is to use a poisonous substance such as *DDT*. When *DDT* was first tried out, it was a very effective mosquito killer. The *DDT* could be dusted over large marshes by slow-flying airplanes or helicopters. One undesirable result, however, marred the success. The *DDT* also killed various small forms of wildlife that we would like to preserve. And then another difficulty arose: in some areas mosquitoes began to develop varieties that were immune to *DDT*. In such areas, it has been necessary to use other types of poisons to effect mosquito control.

So mosquitoes continue to be a health problem in some localities. There is no inexpensive or easy way to eliminate them. Malaria and yellow fever are still hazards in various tropical and semitropical lands.

The housefly. Many people confuse the housefly with the stable fly or with other fly species. They will tell you that houseflies "bite when it is about to rain." These people probably have been bitten by stable flies. A housefly does not bite you for the good reason that it has no biting structures. A housefly lives on liquid foods that it is able to lap up from some surface. It moves around from place to place seeking food, and leaves a trail of germs in its wake.

The habits of various fly species differ, except that all of them lay their



17–13. Stages in the life cycle of a mosquito.

eggs on substances that will serve as food for the young. In some cases, these substances are decaying fruits; in others, decaying meats. Houseflies, however, almost always lay eggs on horse manure. As you can imagine, houseflies were very common back in the "horse and buggy days." Even in cities, manure was available and the flies multiplied rapidly.

17–14. A quiet pool of water is an excellent breeding place for mosquitoes. (*USDA Photo by Madeline Osborne*)

Housefly eggs hatch to produce larvae that feed on the manure. Soon the larvae become pupae, and a few days later the adults appear. The whole development from egg to adult takes only about three weeks. So houseflies produce several new generations each year, and a few flies that survive the winter indoors give rise to a large fly population, as the summer months pass by.

The coming of the automobile and the tractor did much to reduce the housefly population. Horses began to disappear from cities, and then from the farms. Today, houseflies flourish only where manure is still available. The housefly population could have been reduced sooner if horse manure would have been hauled out regularly and spread on the fields. Then the manure dries out, and is no longer a medium in which housefly larvae can survive.

Rats and mice. There are numerous kinds of rats and mice in our world, but two species have been associated with

17–15. Housefly larvae. (*Hugh Spencer*)

mankind for hundreds of years. These species are the house rat and the house mouse. They first lived in the old world, but were brought to our country in the days of settlement. Rats and mice are rodents.

Although they may wander into the fields in warm weather, house rats and house mice tend to collect in homes, barns, and warehouses. House rats also find refuges in the sewer systems of large cities. These two rodent species eat all sorts of foods. They spoil more than they consume, and they chew up various materials to make nests.

17–16. Rats bring about great destruction, especially to stored grain products. (*USDA Photo*)

So house rats and house mice are pests because of the destruction they bring about. But they also are pests, because they harbor the parasites of various diseases that they share with man. House rats, for instance, carry the germs of plague in their blood. Fleas get the plague organisms from the rats, and then convey them to people. Rats and mice may also contaminate foods with germs from their mouths, fur, and waste materials.

Control of rats and mice. Where food is abundant, house rats and house mice produce several broods of young each year. Many cities have rat and mouse populations that outnumber the human population. People usually are not aware of this fact, for the rats and mice are often securely hidden during the daylight hours.

In farm areas, certain hawks, owls, and snakes kill and eat the rats and mice. House mice can be trapped rather easily, but house rats are much more wary. Where they will not be picked up by children or domesticated animals, poison baits can be used to kill the pests. But there is always some danger that the wrong animal will eat the baits. Warehouses and outdoor burrows are sometimes filled with poison gas to wipe out rodent pests, but this is a job for the experts.

DRUG DEFENSES

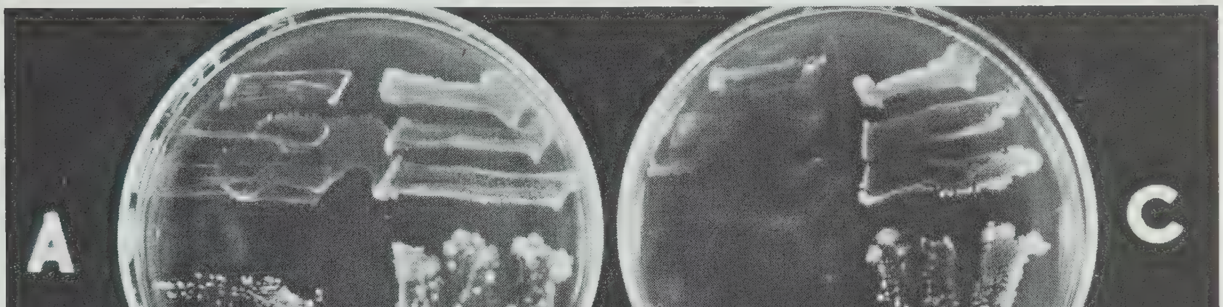
When health safeguards fail, and body defenses are not strong enough to prevent active infections, we must rely upon drugs to combat the threat of

germs. Several new groups of drugs have appeared during the present century. Some of these new drugs provide defenses that are far better than anything available to our ancestors. This is the main reason why the average human life has become much longer in recent times.

Germ killers. For many years, scientists have searched for drugs that will kill or paralyze small parasites. Finding chemical substances that will kill germs has been fairly easy. But most of these substances are too poisonous to be taken into the human body. They can only be used to kill germs on the body surface, and this is how we employ them.

A common example is iodine solution, which is sometimes used to treat cuts and scratches. Iodine solution is an ***antiseptic*** (*an*-tuh-*sep*-tik). This means it will act on germs to kill them or at least slow their growth. However, it is only for use on the outside of the body. There are many antiseptics on the market. Some of them contain *carbolic acid,* some contain *boric acid,* and others contain *mercury compounds.*

The sulfa drugs. The first "miracle" drugs of the present century were the ***sulfa*** compounds. They are ***synthetic*** drugs, which means that they are man-made from chemical substances. As usual, scientists were on the lookout for drugs that would kill germs, but could



17–17. Each of these dishes contains the same four strains of bacteria. An increasing amount of an antibiotic was added to each culture with *A* receiving the least dosage and *D* receiving the strongest dosage. Which one of the four strains of bacteria may be immune to this particular antibiotic? (*Dr. Selman Waksman*)

be taken internally without damage to the host. One sulfa compound that was tested on laboratory animals gave promise of being such a drug.

In 1932 and thereafter, a large number of sulfa compounds were developed. Many of them proved unsatisfactory for one reason or another. But from the hundreds of sulfa drugs tested, a number emerged as very useful additions to our defenses against germs.

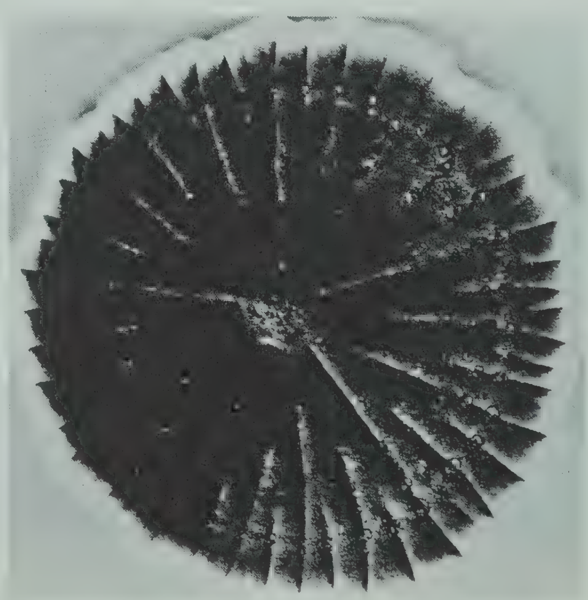
When they first came into use, it was hoped that the sulfa drugs would combat almost any kind of small parasite. This hope proved to be in vain. But it was soon evident that the sulfas were good weapons to use against many bacteria of the *coccus* type. Among these bacteria are over 30 varieties that cause pneumonias. There are also cocci that produce a number of other dangerous infections.

Immune strains of germs. As the sulfa drugs continued to be used, it was found that they no longer were as effective against some germs as they had been. These germs had developed *immune strains* which the sulfa drugs did not affect. Later on, it became known that this sort of thing could happen in the case of many drugs. But what caused the immune strains to develop?

The best theory is that in any germ population there may be a few individuals that are immune or partly immune to a given drug. When people are treated with the drug, the nonimmune germs in this population tend to die out. The naturally immune germs keep on living. These germs multiply by simple cell division, so any young germ has the same qualities as the parent it came from. Among these qualities is the ability to resist the drug. So the immune germs produce more and more of their kind. In time, the germ population contains many immune individuals. Now the drug has lost its one-time potency.

The development of immune strains by germs is one reason why scientists constantly seek new drugs. If one drug loses its value, another can take its place. Then, too, there is always the possibility that a better drug will be found. Maybe the new drug will be easier to take, and maybe it will do a better and faster job of combatting the germs. Remember also that human individuals vary. Here and there, you will find someone who is allergic to a certain drug that does not harm the vast majority of people. If so, this person may be able to take another drug that has the same general effect upon germs.

The antibiotics. In the course of his studies during the past century, Louis Pasteur noted that some bacteria were "antagonistic" to other bacteria. Other scientists followed up this lead. By the end of the century, two extracts from microbes were developed, and they



17–18. The Penicillium mold. (*Photo Courtesy Charles Pfizer & Co., Inc.*)

17–19. Dr. Selman Waksman (left), and Dr. Alexander Fleming (right), discuss soil samples. Name an antibiotic that is credited to each man. (*Courtesy, Rutgers The State University*)

would kill certain germs. One of them served as a drug for a time, but later on its use was abandoned.

Then Dr. Alexander Fleming of England observed an example of this same "antagonism" in 1928. The mold *Penicillium* was killing bacteria in one of his laboratory cultures. Dr. Fleming made an extract of this mold and used it to combat various bacteria. His extract was what we call an ***antibiotic*** (*anta*-bi-*ot*-ik) today. It was named ***penicillin*** (*pen*-uh-*sill*-un), after the mold from which it came.

When World War II began, it was realized that germ-killing drugs would be in great demand. Some other English scientists began to experiment with penicillin, and before long some American drug companies joined in the work. Two of the problems were to develop ways and means of raising the mold in large quantity, and then of extracting penicillin from the mold cells. These efforts were crowned with success. When World War II ended, penicillin had become freely available.

Penicillin is effective against germs of the coccus type, against the bacillus that causes anthrax, and against the protist that causes syphilis. Several types of penicillin are in use today, sometimes in combination with sulfa drugs. A few people react unfavorably to penicillin, but this is to be expected in the case of any drug.

In 1943, the American scientist Waksman, and his associates extracted ***streptomycin*** (*strep*-toh-*mi*-sun) from another type of mold. This antibiotic combatted the same germs that were held in check by penicillin. It also acted against the organisms that cause plague, rabbit fever, and tuberculosis.

Waksman and his co-workers used a process of screening soils in their search for useful molds. This practice of soil screening was soon adopted by a number of American drug firms, and vast numbers of soil organisms were tested. Other useful molds were discovered, and new antibiotics were produced. One antibiotic called ***chloromycetin*** (*klor*-oh-my-*see*-tun) came from a Venezuelan mold in 1947. ***Aureomycin*** (*aur*-ree-oh-*my*-sun) and ***terramycin*** (*terr*-uh-*my*-sun) made their appearance in 1950. Chloromycetin was the first antibiotic to prove effective against typhoid and typhus germs. Aureomycin and terramycin acted against all germs that were sensitive to penicillin, the typhus organisms, and some others.

Since 1950, other antibiotics have been developed. Most of them come from molds, but a few are extracted from bacteria. Scientists have learned to synthesize some of them. When this can be done at low cost, there is no longer any need to raise molds and extract the drugs from them.

Other modern drugs. For many years *quinine* was the only drug availa-

17–20. Quinine is made from the bark of the cinchona tree. (*USDA Photo*)

ble to combat malaria. It was taken to prevent malarial infections, and also to cure them. The story of quinine begins some time before the new world was discovered, when South American Indians learned to chew the bark of *cinchona trees* to relieve malarial fevers. Powdered cinchona bark was brought to Europe in the seventeenth century, and used to a growing extent thereafter. In 1820 the drug quinine was isolated from this bark.

In about the middle of the nineteenth century, cinchona trees were planted in the East Indies. After a time, most of the cinchona bark used by the drug makers came from the East Indian plantations. This source was cut off by the Japanese invasion in World War II. Meanwhile, however, a synthetic drug to prevent and cure malaria had been developed. Since World War II, several other synthetic drugs that combat malaria organisms have become available.

In recent times, other new and promising drugs have been added to our defenses against germs. Among them are compounds that have proved fairly effective in controlling the organism of tuberculosis. Another group also includes new drugs used in the treatment of leprosy.

ANTISEPTICS AND BACTERIA

You have learned that seeds of various kinds will soon be attacked by bacteria of decay, if you let them stand in water. You can easily test the effect of antiseptics upon the growth of such bacteria.

PREVENTING THE GROWTH OF DECAY BACTERIA Put three dry beans in each of six test tubes. Fill each test tube to the half-way mark with water. Treat one test tube as a control, and add a few drops of antiseptic solution to the others as follows:

Tube 1. The control
Tube 2. Add alcohol
Tube 3. Add Mercurochrome
Tube 4. Add antiseptic mouth wash
Tube 5. Add 3 percent hydrogen peroxide
Tube 6. Add iodine solution

Now stopper the test tubes with cotton, and put them in a dimly lighted place at room temperature. Observe what happens each day for a week, and record the results.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did decay products appear in the control tube? Were they largely absent in any of the other tubes? Explain.
2. Were some of the substances tested more effective than others? How so?

3. Of what value is an antiseptic that slows down the growth of bacteria but does not kill them?

HEART DISEASES AND CANCER

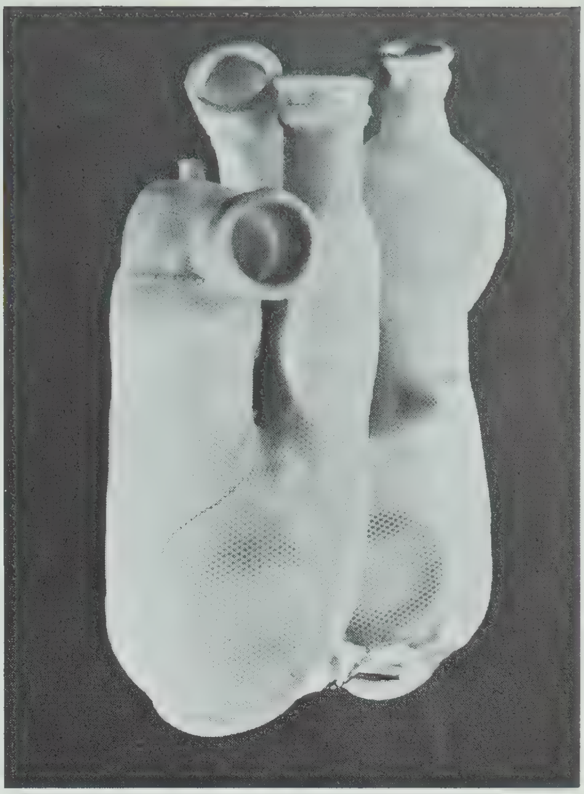
Heart-kidney diseases and cancer cause over half of the deaths that occur in the United States today. Both types of disease are really represented by a number of different ailments. In some cases, they are functional; in others, they are due to infections.

The nature of heart diseases. Some diseases of the heart and blood vessels are caused by germs. Germs can, for example, form colonies on the lining of the heart. They may damage the valves of the heart so that they no longer close properly. After the infection is gone, the damaged valves remain, and a functional disease may develop later.

Other defects of the heart and blood system are purely functional. Some of them are present at birth. An example of this type is when the openings between the auricles and the ventricles of the heart are abnormally small. Not enough blood passes from the auricles to the ventricles.

The normal heart has reserve strength. But this reserve can be overtaxed. If arteries are hardened, the heart must work harder. If heart valves are defective, the heart must also do more work. When the reserve strength of the heart is exhausted, the heart may fail. It is also possible for hardened blood vessels to rupture. Such ruptures may lead to paralysis or death, depending upon the size and location of the blood vessels concerned.

Tumors and cancers. A *tumor* is an overgrowth of cells. Usually it is in the form of a lumplike structure. The cells that form the tumor are growing and dividing at a greater than normal rate. Sometimes a cell divides to produce three new cells, rather than two. In some cases this growth stops after a time, and a wall forms around the lump of cells. The structure is now a simple or *benign tumor,* and when it is removed, it is not likely to grow back again.



17–21. A closeup of an artificial heart which is part of an experimental program directed toward perfecting replacements for diseased hearts. (*UPI Photo Service*)

But some tumors keep right on growing. Then they are *cancers,* and they become a serious threat. Many cancers can be removed successfully, especially if this is done at an early stage in their development. After a cancer growth is established, cancer cells may break free, be carried to other parts of the body, and give rise to added cancerous growths.

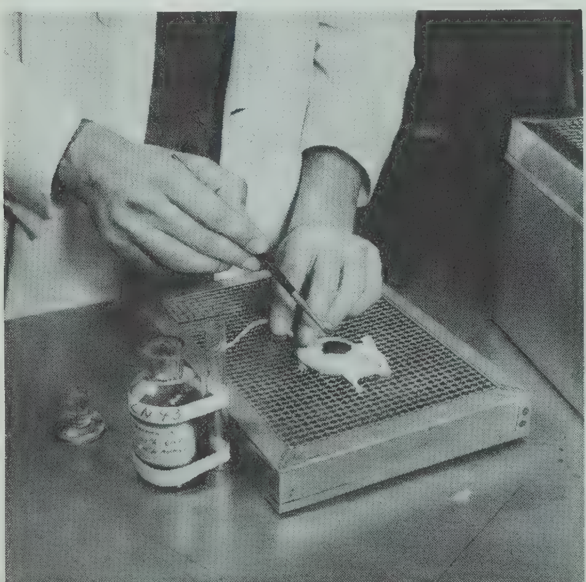
Some cancers form in the skin layer, and others in internal tissues. Signs to look out for are blood coming from any body opening, lumplike growths, indigestion that does not get any better, sores that do not heal, and sudden loss of weight. And remember, cancerous growths usually are *not* painful in their early stages.

Some skin tumors are believed to be due to the presence of viruses. Irritating chemicals, long-continued friction, and heat have all been associated with the development of tumors. It is also known that tumors tend to be common among the members of some families.

ALCOHOL, TOBACCO, AND NARCOTICS

The use of alcohol, tobacco, and narcotic drugs creates a variety of health problems. Some of these problems are far more serious than others.

Tobacco and life expectancy. When the early explorers came to the Americas, they found native Indians smoking and chewing the leaves of tobacco plants. The explorers took pipes and tobacco back to Europe, where the smoking habit became established after a time. From the first, some Europeans were strongly opposed to the use of tobacco. Others thought tobacco might prove to be a useful medicine, but they soon learned that this was a false hope.



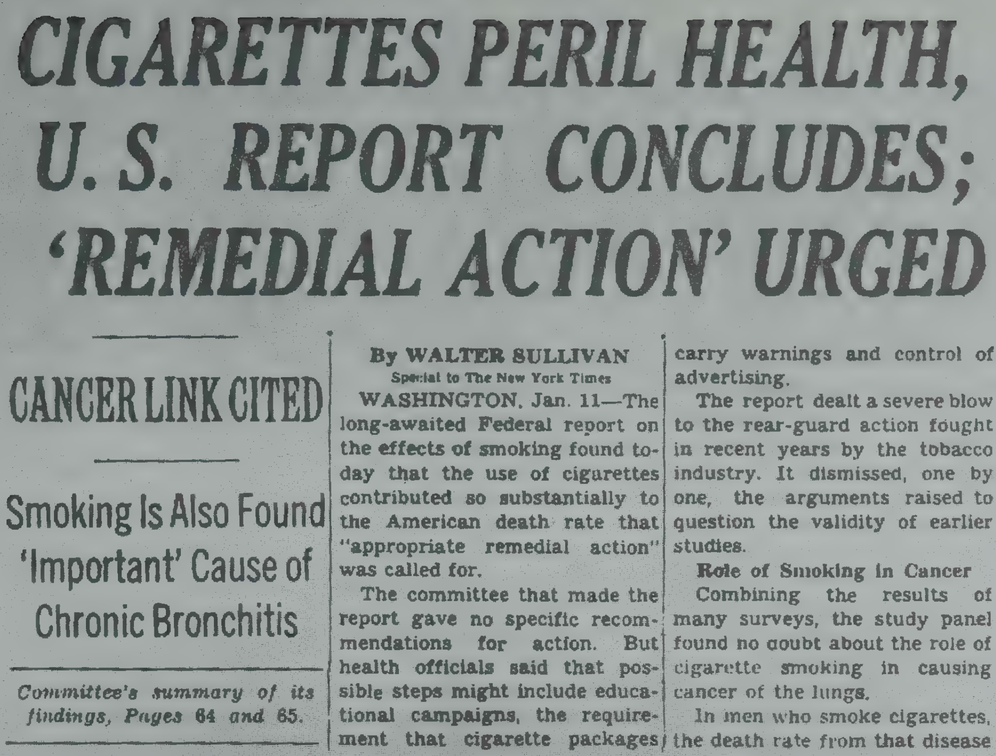
17–22. Tobacco extracts are being painted on a mouse; skin cancer may result. (*American Cancer Society*)

Actually, tobacco contains a poisonous substance called ***nicotine*** (*nik*-uh-teen). You can soak tobacco stems and leaves in water and obtain a brown liquid that is useful in sprays for killing insects. Some nicotine is sure to get into your system, when you use tobacco.

Certain life insurance companies have kept records of heavy smokers, moderate smokers, and nonsmokers for a period of years. The results show that nonsmokers have the longest average life span, moderate smokers come next in line, and heavy smokers have the shortest life span.

In recent years, studies of the cigarette habit have indicated that cigarette smokers are more likely to develop lung cancer than are pipe or cigar smokers, or people who do not smoke at all. Many cigarette users inhale the smoke, and this may, in part, account for the result. There is also an indication that some heart diseases are related to the tobacco habit.

Alcohol and reaction time. Some people are able to take an occasional drink without lasting ill effects. The continued use of alcohol makes alcoholics out of some other people. The only way these people can avoid this fate is not to drink at all. Otherwise, they soon get to the point that they are in an alcoholic daze most of the time. They are unable to work at any responsible



CIGARETTES PERIL HEALTH, U. S. REPORT CONCLUDES; 'REMEDIAL ACTION' URGED

CANCER LINK CITED

Smoking Is Also Found 'Important' Cause of Chronic Bronchitis

Committee's summary of its findings, Pages 64 and 65.

By WALTER SULLIVAN
Special to The New York Times

WASHINGTON, Jan. 11—The long-awaited Federal report on the effects of smoking found today that the use of cigarettes contributed so substantially to the American death rate that "appropriate remedial action" was called for.

The committee that made the report gave no specific recommendations for action. But health officials said that possible steps might include educational campaigns, the requirement that cigarette packages carry warnings and control of advertising.

The report dealt a severe blow to the rear-guard action fought in recent years by the tobacco industry. It dismissed, one by one, the arguments raised to question the validity of earlier studies.

Role of Smoking in Cancer

Combining the results of many surveys, the study panel found no doubt about the role of cigarette smoking in causing cancer of the lungs.

In men who smoke cigarettes, the death rate from that disease

17–23. A New York Times article discussing the federal report on smoking and its relation to disease, especially cancer. (© *1964 by The New York Times Company. Reprinted by permission*)

job because of this condition. Many of them die at a fairly young age.

Another danger of the drinking habit relates to driving cars. To drive a car well you must have a fairly rapid *reaction time.* This is the length of time it takes you to respond, after you have received a stimulus. For example, the driver of a car suddenly sees something run into the road ahead of him. He can miss it if he responds quickly. If he has fast reaction time, he stops or turns to one side. If he has slow reaction time, there may be a tragic accident.

Alcohol slows down reaction time. It may also cause a person to become reckless. Now we have a combination that is very likely to produce a serious accident. The speeding car is in the hands of a driver whose reaction time is too slow. In a recent year, over 40,000 people were killed in motor vehicle accidents in the United States. It has been estimated that one third of all automobile accidents are directly or indirectly related to drinking.

The narcotic drugs. The use of *narcotic* (nahr-*kott*-ik) drugs also has far-reaching and damaging results. To be sure, some of these drugs are used in medicines, because they reduce pain. But in such cases, care is taken so that the users do not become drug addicts.

The drug *marijuana* (*mar*-uh-*wann*-uh) comes from the leaves and flowers of a *hemp plant.* It is sometimes mixed with tobacco to produce the cigarettes called "reefers." Foolish young people may smoke "reefers" for "kicks." Under the resulting effects they may do things they will regret later.

One of the many dangers in using marijuana, however, is that this will

lead to the use of a stronger drug. Marijuana becomes too mild for its victim, and he "graduates" to the use of ***heroin*** (*hair*-oh-in). Heroin is derived from **opium**, a product of the poppy plant. Other drug addicts use ***morphine*** (*mor*-feen), which also is derived from *opium*, or ***cocaine*** (koh-*kayn*), which comes from the *coca plant*.

In all these cases, use of the drug becomes more and more necessary as time goes on. The addict cannot quit the habit without suffering severely. He cannot hold a job, and he often commits crimes to get money for the support of his drug habit. Generally, the end of this road is physical breakdown and death.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column. Write in the statement from the second column that goes best with each of the words.

1. pasteurized	Substance used to kill germs on the body surface.
2. morphine	Any overgrowth of cells in a tissue.
3. nicotine	Drug extracted from a mold or bacterium.
4. antiseptic	Heated enough to kill dangerous germs.
5. marijuana	Poisonous compound found in tobacco.
6. botulism	A type of food poisoning.
7. ptomaines	A narcotic derived from opium.
8. tumor	A drug derived from hemp plants.
9. synthetic drug	Products of protein decay that cause food poisoning.
10. antibiotic	Drug made from chemical substances in the laboratory.

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. A functional disease is one that
   (a) is due to the presence of small parasites in the body.
   (b) is due to inefficient working of some body part.
   (c) does not account for a large proportion of deaths.
   (d) is caused by viruses rather than bacteria.
2. A group of paratyphoid organisms cause numerous cases of
   (a) cancer.
   (b) food poisoning.
   (c) vitamin deficiency.
   (d) functional disease.

3. A cancer is best described as a
   (a) lumplike growth.
   (b) tumor that forms a wall around itself.
   (c) tumor that keeps on growing.
   (d) growth due to an infection.
4. A disease that has often been treated by using the drug quinine is
   (a) typhoid fever.
   (b) plague.
   (c) smallpox.
   (d) malaria.
5. Heroin is
   (a) a habit-forming narcotic.
   (b) a compound obtained from the coca plant.
   (c) a substance used in making cigarettes.
   (d) an antiseptic compound.

SELF TEST

Indicate whether each of the following statements is true or false by writing *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. During the past 50 years the average length of human life has increased.
2. The most common causes of death in the United States today are smallpox and diphtheria.
3. Pneumonia is a functional disease caused by small parasitic worms.
4. The most dangerous type of food poisoning is botulism.
5. After milk has been pasteurized, it is not possible for germs to live in it.
6. If water is full of single-celled algae, it is likely to have an unpleasant taste and odor.
7. Ordinary raw sewage contains relatively few germs.
8. Yellow fever is conveyed to man by mosquitoes.
9. Most mosquitoes lay their eggs on the surface of the ground.
10. The draining of a marsh is always the best way to deal with the mosquito problem.
11. When *DDT* is dusted over a marsh, many small forms of wildlife are likely to be killed.
12. The common housefly is a blood-sucking insect.
13. Most houseflies lay their eggs on manure.
14. House rats and house mice are likely to harbor germs that can produce human diseases.
15. Some diseases of the heart are due to infections, and others are not.

16. Arteries in kidney tissues rarely undergo any hardening.
17. Some tumors are cancers, but others are limited in their growth.
18. The presence of a cancer is easy to recognize, because it is painful, even in early stages of its growth.
19. Data collected by insurance companies indicate that heavy smokers live longer than nonsmokers.
20. Alcoholic drinks have the effect of slowing down reaction time.
21. People who use marijuana often form the heroin habit later on.
22. It is easy to get rid of a narcotic drug habit, even if it is well established.

DISCUSSION QUESTIONS

1. What are some reasons why the average human life has become longer during the present century?
2. What diseases cause the majority of deaths in the United States today?
3. What is the difference between a functional disease and an infection?
4. What are three general types of food poisoning? How do they differ from one another?
5. What germs of cattle sometimes appear in milk? How can these germs affect people?
6. What is meant by pasteurizing, and how is it done?
7. How is water from rivers and reservoirs processed, before it is turned into the city water pipes?
8. Why is stream pollution by sewage a menace to the public health?
9. How are carelessly maintained garbage dumps related to community health?
10. What is done by disposal plants when they process sewage and garbage?
11. How do people get diseases like malaria and yellow fever?
12. How does the draining of marshes affect the mosquito population? In what ways is this control measure unsatisfactory?
13. Why does *DDT* sometimes fail to kill mosquitoes?
14. What is the best way to reduce the housefly population?
15. Why are house rats and house mice so undesirable?
16. What are antiseptics? How are they used?
17. What are sulfa drugs, and what kinds of germs do they control?
18. What is one theory as to how immune strains of germs develop?
19. Why is it desirable to have more than one drug for the control of a germ disease?
20. How was penicillin discovered?
21. What are the sources of the various antibiotics we use today?
22. What is meant by the term "synthetic drug"?

23. Why have cinchona trees had an important relationship to the control of malaria?
24. Are all heart diseases the same? How are they related to certain kidney diseases?
25. What is the difference between a simple tumor and a tumor that is cancerous?
26. What are some signs that may indicate the presence of a cancer?
27. Why should anyone who is about to drive a car avoid the use of alcoholic drinks?
28. How is the use of marijuana related to the heroin habit?

THINGS TO DO

1. Find out what germ diseases have been most common in your community during recent years. Prepare a display chart which lists the diseases, shows their causes, and explains how they are conveyed to man.
2. Prepare several nutrient agar surfaces in petri dishes. Leave all of them exposed to the air for 30 minutes. Now cover half of the petri dishes. Flood the surfaces of the other half with an antiseptic solution, cover them for 10 minutes, pour off the antiseptic solution, and cover them again. Put all the petri dishes in a warm, dimly lighted place. Observe the results daily for about a week.
3. Arrange a class visit to a water purifying plant. Find out where the water comes from, and how it is processed. Arrange a similar trip to observe how garbage and sewage are disposed of in your community.
4. Examine a microscope slide bearing the head and mouth parts of a female mosquito. Find out how this insect pierces your skin when it "bites" you.
5. Study exhibits, such as Riker mounts, that show the eggs, larvae, pupae, and adults of mosquitoes and houseflies. Other insect types, whose life histories may be illustrated by materials in the school collection are cockroaches, lice, and fleas.
6. Prepare a wall chart which shows diseases conveyed to man in food and liquids, and diseases that are insect-borne or arachnid-borne. Consult the references on page 402.
7. Study a mounted specimen (microscope slide) of a tick. This animal is an arachnid. See if you can discover ways in which it differs from an insect.
8. Make a 25 percent solution of ammonia in water. Ammonia is an irritating chemical substance. Paint a small area on the stem of a potted plant with this solution each day for a week. Keep observing the plant, and see if any abnormal growth of cells develops.

9. Collect some examples of plant galls. These are tumorous growths that develop in plant tissues. Cut several of them open with a sharp knife or scalpel. See if you can locate the irritation responsible for the growth.

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BLOCK III

Laboratory Investigations

In Chapters 12–17, you studied how the human body is adapted for life on land. You learned how muscles make movement possible, how food is digested, and how oxygen and energy are obtained. You also read how the body is controlled, and how it may be defended against germs.

In this section, you will find instructions for ways to investigate some of these body parts and processes in more detail. In several experiments, you will have an opportunity to demonstrate some ways in which environmental factors influence body functions. In others, you may observe chemical reactions and activities of lower organisms to gain a better understanding of how your body works.

THE INTERNAL ENVIRONMENT

When skeletal muscles contract, they pull at their bone attachments, and cause body parts to move. As they do this work, muscles use energy and thus must have an energy supply. In animals, energy is obtained from the living things of the environment in the form of food. After food is digested and absorbed, some of it is broken down by a series of complex chemical changes.

These chemical changes require the use of oxygen, which is obtained from the environment by breathing, and is transported to muscles by way of the blood stream. Now foods are oxidized, and energy is released. At the same time, waste materials build up in muscle tissue, and the internal environment of the muscle cells begins to change.

A CHANGE IN MUSCLE ACTIVITY Muscle activity can be influenced by changes brought about through repeated exercise. To demonstrate this, you will need a partner to record the data. You also will need a clock with a second hand. The experiment involves counting the number of times you can make a tight fist and extend your fingers forcefully in fifteen seconds.

When you are ready, begin the exercise using one hand. Have your partner

keep track of the time. Begin a second trial immediately without resting your arm, then a third trial without rest, and so forth. Stop when it becomes uncomfortable to continue. Now rest your arm for ten to fifteen minutes, or until your tired muscles feel comfortable again. After the rest period, repeat the trials again, but this time rest your arm for a full minute between trials. Complete as many trials as before. In your notebook make a copy of the data chart shown below and record your results.

Graph your results using trials as the units of the horizontal axis and number of exercises in 15 seconds on the vertical axis. A solid line can represent the results without rest, and a dotted line can represent the results with rest.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Assuming the muscle environment was changed to a greater degree when you did not rest between trials, what effect did this change have on your muscle activity?
2. What kinds of changes might have occurred in the muscles during the exercises without rest? During the exercises with rest?
3. Describe an experiment that might be done to test the effect of temperature on muscle activity.

EXERCISE AND HEART BEAT RATE Other body cells have needs similar to those of muscle cells. Every cell must be provided with food, oxygen, and certain chemicals. Waste materials must be carried away, and a favorable temperature must be preserved. In short, the cells of the body survive only when the internal environment is maintained within certain limits. In Chapter 12, you learned that the blood is involved in the maintenance of the internal environment. So you might predict that the movement of blood is carefully geared to the needs of body cells. If, for instance, your muscle cells are required to work rapidly, and their internal environment begins to change, the change must be resisted if the cells are to survive. The blood plays an important role in opposing such changes.

As you know, the heart is a blood pump. When the heart contracts, blood is pushed through blood vessels. One of these vessels is close to the surface in your wrist. You can feel a surge of blood passing through it each time the heart beats. We call this surge of blood the *pulse*. You can demonstrate a response of the heart to exercise by doing the following:

Measure your pulse rate by placing a finger on the underside of the wrist just below the base of the thumb. For practice, count the number of pulse beats for one minute. Now sit quietly for two or three minutes. Determine your pulse rate while you are resting. Make three measurements, calculate

	Number of exercises in 15 seconds										
Trial	1	2	3	4	5	6	7	8	9	10	11
Without rest											
With rest											

the average, and record the results in your notebook. Next, stand up, and while standing, measure your average pulse rate as before. Unless there is some reason why you should not exercise, hop up and down on one foot, as fast as you can, twenty times. As soon as you have completed the exercise, measure your pulse rate. Sit down and count your pulse every two or three minutes, until the rate is close to the rate you found while resting. Keep track of how long this takes.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did your heart seem to "sense" the change produced in your body by standing? Explain.
2. How long did it take for your heart beat rate to return to the rest level following exercise? What do you think was happening between the blood and muscles during this time?
3. Did you notice any other body responses following the exercise? What were they?
4. How do you think the body "senses" internal changes?

DIGESTIVE ORGANS AND ENZYMES

THE DIGESTIVE SYSTEM OF A FROG Digestion is the process whereby complex food molecules from the environment are broken down into simpler forms. Food molecules must be in a simple form before they can be absorbed and used. This breakdown is controlled by special chemicals called enzymes, which are made by various digestive organs.

If you have a specimen available, examine the digestive system of a frog. To do this, cut through the skin and muscle layer from the anal opening to the jaw. Next, cut along each side, and remove the skin-muscle layer from the entire underside. In the neck area, you will have to cut through bones connected to the front legs. Use heavy scissors. If your frog is a female, you probably will find the body cavity filled with dark colored eggs. These can be lifted out so you can examine the digestive organs beneath.

The largest organ you will see is the liver, which fills much of the space in the upper half of the body cavity. Just above the liver, in the center of the body cavity, is the heart. Note that the heart has three chambers. The liver has three lobes. If you spread them apart you can see a greenish, ball-like object which is the gall bladder.

Beneath the liver, on the frog's left side, is a large tubelike structure. This is the stomach. Leading away from the lower end of the stomach is the small intestine, which joins the large intestine. Attached to the outside of the lower part of the stomach is the pancreas. Note how the digestive tube narrows at the point where the small intestine begins. This is the location of the valve that controls the movement of food from the stomach into the intestine.

Carefully remove the pancreas and a short section of the small intestine, close to the stomach. Rinse these parts in water and keep them refrigerated. They will be needed to complete the experiment described on page 406.

Before you discard your frog, note

the lungs, which are just beneath the liver. They may appear as long, bubble-filled masses. The kidneys can be seen as long, dark reddish organs on either side of the backbone. Above the kidneys are some yellowish, fingerlike parts called fat bodies.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Describe each of the parts of the digestive system. Be sure to include size, color, shape, and texture in your description.
2. In what ways are the shapes of the parts related to their functions?
3. After digestion, the products are absorbed through the wall of the digestive canal and are carried away in the blood. Did you observe any blood vessels associated with the digestive canal that might function in this way? Explain.

STARCH DIGESTING ENZYMES Starch is a common substance in plant materials. It is composed of rather large molecules and, of course, must be digested before any part of it can be absorbed through the wall of the digestive canal. In human saliva, the enzyme ptyalin, breaks down starch molecules into smaller sugar molecules.

Prepare a starch suspension by boiling one part of starch in twenty-five parts of water. After the suspension has boiled for a few minutes, allow it to cool. Now test a small sample for the presence of sugar. Follow the instructions for the sugar test found on page 318.

Collect some saliva by chewing a bit of paraffin and spitting into a test tube. Test a small quantity of saliva for sugar. If sugar is present, use saliva from someone that tests negatively.

Place about half an inch of starch suspension in each of four clean test tubes. Treat the tubes as follows:
Tube 1. Add half an inch of saliva.
Tube 2. Add half an inch of saliva which has been boiled for a minute.
Tube 3. Add half an inch of saliva and ten drops of dilute hydrochloric acid.
Tube 4. Add nothing.
(If you saved the pancreas and a section of small intestine from the frog observation, described on page 405, prepare two additional tubes of starch suspension. Cut the pancreas into fine pieces and grind it up in a little water. Test a small sample of the resulting material for the presence of sugar and add the remaining part to *Tube 5*. Similarly, cut the section of small intestine into pieces, grind it in a little water, and test a small sample for sugar. Add the remainder to *Tube 6*.)

After about 30 minutes, test a sample from each tube for the presence of sugar. Record your observations in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In which of the tubes did digestion of starch occur? How would you explain these results?
2. In what way is the enzyme in saliva affected by boiling? By hydrochloric acid?
3. Are starch digesting enzymes present in the frog pancreas? In the small intestine? What evidence do you have?

4. How could you find out if the rate of starch digestion is affected by temperature?

VITAMINS

In Chapter 13, you learned that vitamins make up a group of chemicals necessary for proper body functioning. These chemicals are present in foods and if we eat a variety of things we usually get the vitamins we need. However, it is known that some vitamins are affected or even destroyed by the way food is prepared.

INVESTIGATING THE EFFECT OF CERTAIN FACTORS ON VITAMIN C Vitamin C or ascorbic acid is readily available in drug stores and food markets. It can be purchased in a solution or tablet form. An indicator useful in testing for the presence of vitamin C is called sodium 2,6, dichlorobenzenone or indophenol. It can be obtained from biochemical supply houses.

Make a 0.1% solution of indophenol by dissolving one gram of indophenol in 1000 milliliters of water. Dissolve a vitamin C tablet or some vitamin C solution in a small quantity of water. Place about 5 ml of indophenol solution in a clean test tube and add a drop of the vitamin C solution. If the indophenol turns from blue to colorless with only one drop of vitamin C solution, the vitamin solution is too strong and must be diluted with water. Add water until it takes ten to fifteen drops of vitamin solution to cause 5 ml of indophenol to become colorless. Once the vitamin solution is adjusted, use samples of it to test the factors described below for their effect. In each case be sure to keep a second sample of vitamin C solution as a control.

Freeze a sample of vitamin C solution. Keep a second unfrozen sample as a control. Thaw the frozen sample and test both for the presence of vitamin C. See how many drops of each it takes to decolorize 10 ml samples of indophenol. If more drops are needed for one sample then less vitamin C is present.

Boil a sample of vitamin C solution for several minutes by submerging a test tube in a beaker of boiling water. Keep a second sample at room temperature for a control. Test each for vitamin C, as before.

Leave a sample of vitamin C standing in a container, exposed to air for at least 24 hours. A control sample should be placed in a tightly sealed container at the same time. Try to prevent air from remaining in the container. Keep both samples in a dark place at room temperature. Test for vitamin C.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. What factors seem to affect vitamin C the most? The least?
2. How should foods be treated to preserve the vitamin C content?
3. How could indophenol be used to find out which fruit juices provide good sources of vitamin C?

RESPIRATION AND CARBON DIOXIDE

Many organisms obtain the energy stored in the chemical bonds of food molecules, by a process called *respira-*

tion. This process involves *oxidation* of the food molecules. In oxidation, oxygen is combined with carbon from food molecules to form carbon dioxide. The carbon dioxide is a waste product and is given off to the environment in various ways. In your body, carbon dioxide is transported by the blood from body cells to the lungs. It is given off from the lungs as you exhale.

BROMTHYMOL BLUE AS AN INDICATOR OF CARBON DIOXIDE When carbon dioxide is dissolved in water it forms a weak acid. The presence of acids can be detected by using certain chemical indicators. Bromthymol blue is such an indicator, since it is *blue* in the presence of a base and *yellow* in the presence of an acid.

Prepare a stock solution of bromthymol blue by dissolving 0.5 grams in 500 milliliters of water. If the resulting solution is not a deep blue color, stir in single drops of dilute ammonia water until it is. Prepare some dilute indicator, by adding some of the stock solution to another container of water, until the water is a light blue color.

Pour samples of the dilute indicator into each of nine test tubes. Seal the tubes with stoppers, and keep them sealed until they are used. Treat the tubes as described below. In each case, predict the results before you perform the test. You will be looking for color changes in the indicator. Write your prediction in your notebook, and explain why you predicted as you did.

Tube 1. Leave this tube as a control.

Tube 2. Remove the stopper and blow your breath through a straw, so it bubbles into the solution. Continue blowing for several minutes.

Tube 3. Place a small, aquatic animal such as a snail, guppy, or tadpole in the solution. Reseal the tube.

Tube 4. Place a small piece of aquatic plant in the solution. Reseal the tube, and keep it in a lighted place.

Tube 5. Add a piece of aquatic plant as in *Tube 4,* but keep it in a dark place.

Tube 6. Remove the stopper and leave the tube open to the air.

Tube 7. Boil a dried bean for a few minutes in another tube of water. Put the boiled bean in *Tube 7* and reseal the tube.

Tube 8. Put a few ml of yeast suspension together with a few ml of glucose solution in the tube.

Tube 9. Repeat *Tube 8,* but omit the glucose solution.

Observe each tube daily for several days and record any color changes.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. In which of the tubes was the presence of an acid indicated? Explain these results.
2. Are you sure that the color changes were due to the presence of carbon dioxide? How so?
3. What was being tested in the case of the boiled dried bean? What evidence do you have?
4. What did the results with *Tube 6* seem to indicate?
5. Assuming that the color change was due to carbon dioxide, what can you say generally about the living things tested?

INVESTIGATING CARBON DIOXIDE PRODUCTION FROM YEAST CELLS Yeasts are single-celled, nongreen plants. As nongreen plants, they must obtain food from an outside source. In addition, yeasts can carry on respiration. That is, when oxygen is present, yeasts can break sugar down into water and carbon dioxide. When oxygen is in low supply, they may carry on fermentation, which results in the production of carbon dioxide and alcohol. In either case, the energy released from the food is used to carry on the activities of the cells.

We can use the amount of carbon dioxide released by a group of yeast cells in a given amount of time as a measure of the rate the cells are using food materials.

Prepare a suspension of yeast cells by stirring a small package of activated dry yeast into a liter of water. Put about 100 ml of the suspension in a separate container and set it aside. To the larger portion, add some sugar or a sugar-containing substance. Ten to fifteen grams of glucose or ten to fifteen ml of molasses or grape juice should prove satisfactory.

Fill four small beakers about half full of yeast and sugar solution. Fill four small test tubes with the same mixture. The tubes must be filled to the top. Now place your finger over the end of a tube so that the contents cannot leak out. Invert the tube into one of the beakers of yeast-sugar solution. Do not release your finger until the mouth of the tube is under the liquid in the beaker. Place the other tubes in the beakers, using the same procedure. Treat the beakers as follows:

Beaker 1. Put it in a dark place at room temperature.
Beaker 2. Keep it in a lighted place at room temperature.
Beaker 3. Put it in a dark, cool place such as in a refrigerator.
Beaker 4. Put it in a dark, warm place, such as near a heater or in a warm water bath.

Use the sample of yeast suspension without sugar, that you saved, to set up another beaker-test tube and place it in a dark place at room temperature. Note the time you finished setting up the preparations. Check them every 20 minutes for the next hour or longer, if possible. Record the millimeters of gas that collects in each of the tubes.

Make a copy of the data chart for your notebook. Calculate the rate of gas formation for each tube.

Tube Number	mm of gas	Length of Time test Ran	Rate of gas Formation In mm/hr
1			
2			
3			
4			

ANALYSIS Prepare answers to the following questions in your notebook:

1. What conditions seem to favor carbon dioxide production by yeast cells? Explain.
2. Which of the tubes served as control tubes? How so?
3. Were your observations qualitative or quantitative? Explain.
4. How could you find out if the amount of carbon dioxide produced is influenced by the presence of certain chemicals?

ENVIRONMENT AND BEHAVIOR

INVESTIGATING THE EFFECT OF CERTAIN FACTORS ON BEHAVIOR What you do and the way you do it often is influenced by information you have gathered through your senses. They record changes in the environment, and sometimes you react to the changes. For example, if an object moves close to your face, you blink. If the brightness of light changes, the pupil of your eye changes also. You may react by sneezing or coughing, if pollen is present. If the amount of carbon dioxide in the air changes, your breathing rate will change. In each of these cases, your pattern of behavior is *inborn*. The reactions are automatic or *involuntary*. You have very little control over such reactions.

In other instances, your behavior is not automatic. If you are sitting in the sun and get too warm, you may get up and move into the shade. If you are too cold, you may move to a warmer place or put on a coat. If you see something interesting, you may move toward it. Or if something threatens you, you may run away. In these examples, your reactions are *voluntary*.

Think back to your activities of the day, and prepare a list of those that probably were responses to factors in your environment. For each item in your list, indicate whether the reaction was voluntary or involuntary.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. Can you think of any kind of behavior that is not related to the environment? Explain.
2. Do you think that the responses on your list were examples of inborn or learned behavior? How so?
3. What part does habit play in the way you respond to the environment?

INVESTIGATING CONDITIONING IN ANIMALS Animals often respond to changes in their surroundings by reflex actions. A given reflex is usually triggered by a certain type of change or stimulus. You studied such a reflex of the eye, and discovered that iris-contraction is a response to the presence of bright light.

Biologists have learned that the pattern of reflex actions can sometimes be changed. After such a change, the reflex is triggered by some new stimulus instead of, or in addition to, the usual one. The bringing about of this type of change is called *conditioning*.

It may be possible for you to demonstrate such a change in behavior, using an animal as a subject.

Obtain an aquarium and a few fish. Each day feed the fish a small quantity of food at one end of the tank. Just before you feed them, present them with some stimulus, in addition to the food. That is, tap the side of the glass or flash on a light. It is important to keep the fish hungry and to present the new stimulus very shortly before feeding them.

Repeat this procedure every day for a week. At the end of that time, present the new stimulus without feeding the fish. If they do not respond, continue presenting the stimulus with the food for a second week.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What are the essential steps in conditioning an animal?
2. Do you think that lower animals, such as earthworms, can be conditioned? How could you find out?
3. Can people be conditioned? What evidence do you have?

AN EFFECT OF LEARNING ON BEHAVIOR In your everyday living, you use symbols much of the time. For example, you have learned that letters, numbers, and sounds in certain combinations have certain meanings. Others have learned similar lessons, and as a result, you can communicate with them.

It is interesting to note how strongly you have learned to associate certain words with actual objects or experiences. You may associate the word "lemon" so strongly with the taste of the fruit, that just reading the word causes your mouth to water. Or you may actually experience pleasant or unpleasant feelings upon seeing certain words. In some cases, your reactions may be so strong that many of your body parts are affected. A person with a great fear of snakes might experience changes in his muscles, heart, stomach, or intestines after reading or hearing of "snakes."

Have you learned to react to any of the following words? Read each word or phrase in the list, and decide if it provokes a pleasant or unpleasant feeling. If pleasant, write "+" after the number of the word in your notebook. If unpleasant, write "−," and if the word is neither pleasant nor unpleasant, write "0."

1. rats
2. meadow
3. cliff
4. tree
5. spiders
6. thunder
7. sea shore
8. deep water
9. island
10. alone
11. disease
12. speeding
13. tramp
14. gun
15. flower
16. bleeding
17. bee
18. fire
19. vaccination
20. mad dog
21. knife
22. burglar
23. falling
24. lightning
25. night
26. fair
27. airplane
28. bats
29. poison
30. ice cream
31. spanking
32. movie
33. television
34. summer camp

People who design advertisements for newspapers, magazines, television, and radio often hope that viewers and listeners will learn to associate their products with pleasant feelings or experiences. In this way, the advertisements may influence the behavior of buyers.

See if you can find examples of such advertisements, and make a collection of them. For each item, indicate how you think the advertisement is designed to influence behavior.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What kinds of words provoke pleasant feelings? How do you explain this?
2. What kinds of words provoke unpleasant feelings? Explain.
3. Would you say that symbols make up an important part of your environment? How so?
4. In what way is a response to a word or symbol like conditioning?

PROBLEM SOLVING BY TRIAL AND ERROR

You have learned that behavior may be automatic or based on past experience with objects or symbols. Sometimes the environment presents situations that are new, and if responses are necessary, you are faced with a problem to solve. That is, you have to discover what behavior is most appropriate to a particular situation.

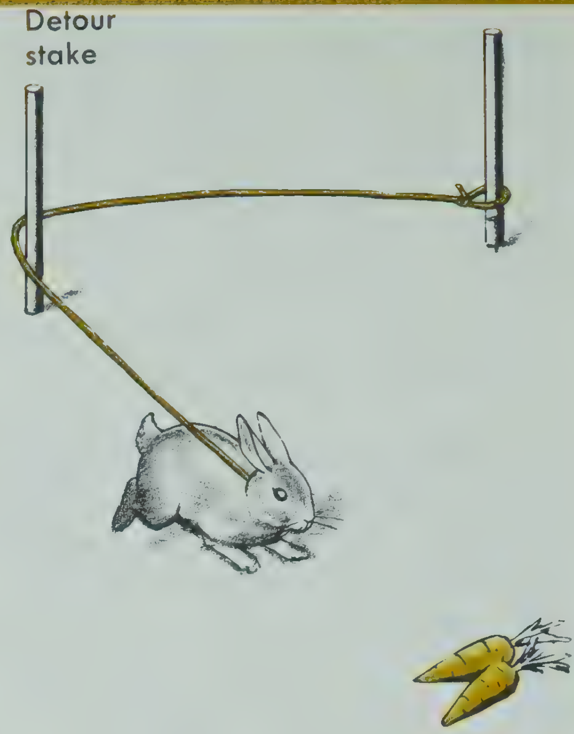
Biologists have devised situations that require problem solving by animals. One is called a *detour problem.* The animal being studied may be tied to a rope that is too short to reach a dish of food that the animal can see and smell. However, if the animal first moves away from the food and walks around a detour stake, the rope will be long enough to reach the dish.

Such a problem certainly would be a simple one for you, but very few animals are successful the first time they are faced with the situation.

How can such problems be solved? One way is by simply trying one thing after another until a solution is reached. We call this method *trial and error.*

An animal, placed in a box containing a network of pathways called a *maze,* must find its way out by trial and error. Perhaps you have tried to find your way through a maze at a fair or a beach fun zone. Or you may have seen a maze puzzle in a book or magazine.

You can test your ability to solve such a problem by doing the following. Obtain a piece of colored construction paper or light weight cardboard. Cut an opening no larger than one-fourth inch in diameter out of the center. There is a maze printed on page 413 of this book. *Do not look at it until you are ready to perform the test.* When ready, turn to the maze, and quickly place the cardboard over the maze. There is a star in the upper left hand corner of the page. Center the star in the opening cut in the cardboard, then move the cardboard so that you can follow the line of the maze.



L–1. A detour problem. How can the rabbit get the carrots?

There is a dot at each intersection and deadend. As you try to find your way to the end, keep track of the number of dots you meet. Once you reach the end, move the cardboard so that the opening is at start again. Repeat this procedure until you are able to move from the start to end without error. *Be sure to keep the maze covered at all times.* In your notebook, make a copy of the data chart on page 413 and keep track of your results. Twenty-four hours later, try the maze again using the same procedure and record the results.

L–2. A maze will demonstrate learning by trial and error.

Prepare a graph of your data using trials as the units of the horizontal axis and number of dots seen as the units of the vertical axis. A solid line can represent the first day's data and a dotted line the second day's data.

Trials	Number of dots seen	
	Series 1	Series 2
1		
2		
3		
4		
5		

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did the *trial and error* method prove useful in solving the maze problem? Explain.
2. Did you solve the maze problem rapidly or slowly? Is this characteristic of trial and error solutions? How so?
3. What did your second day results indicate?
4. What other methods do you use to solve problems?

FACTORS THAT AFFECT MEMORY When faced with a situation like the detour problem, you sometimes "see the solution" almost immediately. This is because you have the ability to *reason* or solve complex problems. When you reason, you draw on your past experiences and apply what you have learned to some new situation. Just how problems are solved this way is not well understood. However, it is known that *memory* is involved.

You have, no doubt, been asked to memorize rules, ideas, poems, lists of words, and combinations of numbers. You still remember some of what you have memorized. Some you have forgotten. Do you suppose the environment has any influence on the way you memorize, remember, and forget?

Study *List 1* (nonsense syllables) until you can make a copy of it from memory without error. Keep track of the time it takes to complete this task successfully. Be sure to work in a quiet room. Now memorize *List 2* (nonsense syllables) using the same procedure. But this time, ask someone to talk or read jokes to you while you work. Once again, keep track of the time it takes. After you have finished the second list, see how much of the first one you remember. Try to make a copy of it without review.

List 1	*List 2*
JIK	ZOK
BEJ	RAL
LOR	FAZ
ZAF	TOC
CEB	MIB
MAZ	SED
VIB	HAK
MEM	LIX
KOZ	NAJ
BIR	VEB

Now memorize *Lists 3* and *4,* following the same procedure. Keep track of the time it takes for each.

List 3	*List 4*
LAMP	THEIR
PENCIL	PLAYER
SHOE	RACED
DESK	DOWN
TREE	THE
BOOK	FIELD
WINDOW	FOR
PAPER	HIS
COAT	SECOND
SPOON	POINT

ANALYSIS Prepare answers for the following questions in your notebook:

1. What difference did you find in the time it took to memorize the first and second lists? How do you explain this?
2. How well could you remember the first list after memorizing the second? How do you account for this?
3. Lists 3 and 4 consist of familiar words. Why is it easier to memorize List 4?
4. What environmental factors probably affect your ability to memorize? What evidence do you have?

MICROORGANISMS

TESTING FOR THE PRESENCE OF BACTERIA AND FUNGI Bacteria, fungi, and other microorganisms are found almost everywhere. They occur in soil, water, and air. They can be found on the outside of living things and inside their bodies. Although some of these microorganisms are parasites and cause disease, most of them are harmless. In fact, many of them are helpful, because they cause decay. As you learned in Chapter 11, decay is an important process in every natural community. It is by decay that necessary chemicals are released from the bodies of dead plants and animals and returned to the soil.

Some microorganisms produce a special type of cell called a *spore.* Spores generally have thick protective coverings and can resist drying. In this spore form, many kinds of bacteria and fungi travel in air. They drop as dust particles and if they happen to land in a favorable environment, they begin to grow and reproduce.

You can demonstrate the presence of such microorganisms in your surroundings by providing favorable conditions in culture dishes. To do this you will need some nutrient agar. This can be purchased from biological supply houses or you can prepare some by dissolving the following chemicals in a liter of water:

Peptone	5 grams
Beef extract	3 grams
Table salt	5 grams
Agar	15 grams

This mixture must be heated and stirred until all of the materials have dissolved. It will be necessary to boil the water before the agar will dissolve.

Pour samples of the melted nutrient agar into each of eight petri dishes until a thin layer is formed. Put the tops on the dishes, and sterilize them to kill any microorganisms that might already be present. This can be done by placing the dishes in coffee cans and then cooking them in a pressure cooker. Be sure that there is about an inch of water in the cooker before you begin the heating process. Cook the dishes for twenty minutes at fifteen pounds of pressure. Let the cooker cool, and remove the petri dishes while they are still hot. Let them dry in air. As they cool the agar will solidify.

The culture dishes are now ready to use. The solid nutrient agar provides a surface on which bacteria and fungi can grow. A supply of food, water, vitamins, and minerals is available in the agar, and many forms can grow in the darkness at room temperature.

If a single spore reaches the surface of the nutrient agar, we can expect it to grow and reproduce. The newly formed cells can also grow and reproduce, and in time, a large *colony* of cells should be formed. Although we cannot see a single spore with our unaided eyes, we can see colonies made up of thousands of cells tightly packed together.

To test for the presence of microorganisms, expose the surfaces of your culture dishes to various things. Be sure to close the dish as soon as you have finished exposing it. You might want to expose the first few dishes as follows:

Dish 1. Leave unopened.
Dish 2. Press your fingers lightly on the surface of the agar.
Dish 3. Remove the top and leave the dish open to the air for 15 minutes.
Dish 4. Allow a drop of water to drop into the dish from a faucet. Tip the dish so the water spreads evenly over the agar surface.
Dish 5. Using a piece of sterile cotton, brush some dust into the dish.
Dish 6. Capture a fly and let it walk around inside the dish on the agar.
Dish 7. Cough or sneeze on the agar surface.
Dish 8. Touch the agar with a clean handkerchief.

After each dish has been exposed, label it and tape it closed. Put the dishes in a dark place at room temperature, and check them daily for several days for signs of growth. When you finish your study resterilize the dishes before opening them.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How common are microorganisms in your surroundings? What evidence do you have?
2. What was the purpose of leaving *Dish 1* unopened? What did you find out from this dish?
3. In what ways are microorganism colonies similar? How are they different? What evidence do you have for your answers?

SUMMARY: BLOCK III

The human skeleton gives support to the body, and provides protection for internal structures. To it are attached the muscles that make it possible for us to walk, run, and engage in many different activities. The skeleton is made up largely of bone, with some cartilage at the ends and sides of the bones. There are over 200 bones in the human body.

Muscle tissues are of three types: the voluntary muscles, the involuntary muscles, and the heart muscles. We control only the actions of the voluntary muscles. A muscle is a mass of muscle cells held together by connective tissue. Such a muscle contracts to move parts of the skeleton or to change the shape and size of a fleshy structure within the body.

Human blood contains a basic fluid called plasma, which transports foods, wastes, and hormones. Plasma contains antibodies, which are chemical substances that combat invasion by germs. In the plasma are many red corpuscles, which are oxygen carriers, and a smaller number of white corpuscles. Some of the white corpuscles are able to destroy germs.

Arteries carry blood from the heart to the body tissues, and veins carry blood from the body tissues back toward the heart. In the tissues, networks of tiny capillaries connect the ends of arteries with the veins. Plasma escapes from the capillaries and becomes tissue fluid. Some tissue fluid re-enters the capillaries, and some of it enters lymph vessels and becomes lymph. Lymph vessels discharge into veins.

The human digestive system consists of organs and associated glands. The glands secrete digestive enzymes. Digestion begins in the mouth, where an enzyme of saliva changes starch into sugar. The food goes down the esophagus and enters the stomach. Here, enzymes of the gastric juice begin the digestion of proteins. At the end of the stomach a valve opens at regular intervals to permit the food to pass on into the small intestine.

Food needs vary depending on age, sex, activity, and individual differences. A small child may require as little as 1,000 Calories a day, but an adult man doing heavy work may require 5,000 Calories. Foods vary in their Calorie content. A pound of butter contains 3,500 Calories,

but a pound of fish contains only 300 Calories. Foods also vary in their protein, carbohydrate, and fat content, and in the amount of roughage they contain.

The body must have adequate amounts of certain vitamins, or deficiency diseases may develop. Vitamins are present in various common foods. But people who eat only a few kinds of foods may lack sufficient vitamins. Deficiency diseases include beri-beri, pellagra, scurvy, and rickets.

The brain is the highest control center of the human nervous system. It consists of a cerebrum and a cerebellum that are attached to a brain stem. The cerebrum is the center for memory, sight, and hearing; it directs our conscious acts. The cerebellum is largely concerned with maintaining body balance and coordinating muscular activities. The rear portion of the brain stem is the medulla, which connects the rest of the brain with the spinal cord. The medulla exercises automatic controls over breathing motions and the beating of the heart. The spinal cord is an important reflex center, and also a pathway for messages going to and from the brain.

Some of our acts are reflexes that are automatic, but we can control other reflex acts to some extent. Habits are acts that have been repeated so often that they have become, at least partly, automatic. Memory is the ability to recall past events, and intelligence is the capacity to learn. Knowledge includes everything you have learned and can recall.

Other body controls are exercised by hormones from the ductless glands. The hormone insulin, from the pancreas, is necessary to the normal use of sugar in the body. Thyroxin from the thyroid gland affects the rate at which oxidation takes place in the tissues. Adrenalin from the adrenal glands controls the state of contraction in the muscle tissue of blood vessels. Other hormones influence the sex organs, kidneys, blood content, and the nature of growth and development.

Many germs are conveyed to man by contact or near-contact. Others enter the body with foods and liquids, and some are insect-borne or arachnid-borne. The body has natural defenses such as the skin barrier, the acid of gastric juice, the organisms that are resident in the digestive canal, and the white corpuscles and antibodies of the blood.

Antibodies provide the protection we call immunity. Antibodies formed in your own cells produce active immunity. Antibodies conveyed to you from the blood of another animal produce passive immunity. Today, we use vaccines to produce active immunities to a number of diseases. Some immunities are relatively strong, and others are only partial. Some are short-lived, and others are more lasting.

To maintain the public health requires constant vigilance. People must receive vaccines so that they will be immune to certain diseases. Foods

and drugs are safeguarded, so that they meet standards of purity and safety. Water supplies must be free from dangerous contamination. Garbage and sewage should be disposed of in a sanitary manner. Insects, arachnids, and rodents, involved in spreading diseases, must be brought under control.

When safeguards fail, and germs produce infections, in spite of body defenses, we rely upon the use of drugs. During the present century a large number of new and more effective drugs have been developed. These drugs have played a major role in lengthening the average human life.

Most of the deaths in our country now result from heart-kidney diseases and cancer. In part, this probably is because people now live long enough to develop more diseases of these types.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. bromthymol blue	A chemical that turns yellow in the presence of an acid.
2. fermentation	A method of problem solving.
3. nutrient agar	A food substance that is changed to sugar by digestion.
4. pulse	Method used to kill microorganisms.
5. small intestine	Material used to culture bacteria and fungi.
6. starch	Surge of blood passing through a blood vessel in the wrist.
7. sterilizing	A process resulting in the formation of carbon dioxide and alcohol.
8. trial and error	Tube leading away from the stomach.

B

1. carbon dioxide	A special cell that resists drying.
2. colony	A network of pathways.
3. enzyme	Yellow, fingerlike parts in the frog.
4. fat bodies	Single-celled nongreen plants.

5. maze	A group of cells growing tightly packed together.
6. saliva	Chemical that functions in protein digestion.
7. spore	Liquid that contains a starch digesting substance.
8. yeasts	A waste product of respiration.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Muscle activity may be influenced by changes in the internal environment.
2. Body cells can survive almost unlimited changes in the internal environment.
3. Blood movement is unrelated to body cell needs.
4. Each beat of the heart produces one beat in the pulse.
5. The heart is the largest organ in a frog.
6. The body cavity of a female frog is sometimes filled with eggs.
7. The large intestine leads away from the stomach and joins the small intestine.
8. The pancreas is attached to the outside of the large intestine.
9. At the point where the small intestine begins, there is a muscle that controls the flow of food into the lower digestive canal.
10. In a frog, the kidneys are yellow, fingerlike organs.
11. You usually get the vitamins you need if you eat a variety of foods.
12. Indophenol is an indicator that is blue in the presence of vitamin C.
13. The release of energy from food molecules is called digestion.
14. Bromthymol blue is used to locate enzymes.
15. Yeast cells contain chlorophyll and can make their own food.
16. Carbon dioxide is carried from body cells to the lungs by the blood.
17. Inborn behavior is learned behavior.
18. Most animals can solve the detour problem in their first attempt.
19. A maze is solved by trial and error.
20. Most microorganisms are disease causing parasites.
21. Decay should be considered as being helpful to natural communities.

DISCUSSION QUESTIONS

1. What must happen to food before energy can be released from it? Explain in detail.
2. What is meant by the "internal environment"?
3. What conditions favor the survival of body cells?
4. Explain how the pulse rate is related to the heart-beat rate.
5. In what ways is the digestive system of a frog similar to that of a human? How are they different?
6. How does saliva function in digestion?
7. Distinguish between respiration and fermentation.
8. How is the carbon dioxide produced in body cells removed from the body?
9. Define and name examples of a chemical indicator.
10. In what ways are yeast cells similar to animal cells?
11. Distinguish between inborn and learned behavior. Describe examples of each.
12. What is conditioning?
13. How can conditioning be an advantage? A disadvantage?
14. What factors are related to the differences in the behavior of children and adults?
15. Distinguish between problem solving by trial and error and problem solving by reasoning. Describe examples of each.
16. How is trial and error used in everyday living?
17. How is memory related to reasoning?
18. Are organisms other than man influenced by symbols? What evidence do you have?
19. How can the study of environmental influence on memory be used to improve study habits?
20. How would you explain the fact that microorganisms are found almost everywhere?
21. In what way do spores function in the survival of microorganisms? Explain.
22. What is the relationship between the number of microorganisms that enter a culture dish and the number of colonies that form?

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BLOCK IV

Production and Control

Our earth is about five billion years old, and during the first three billion years of its existence it probably had no inhabitants. In fact, it did not look very much like the earth of today. The atmosphere that surrounded this young earth differed from our present atmosphere. The young earth was probably blanketed by a mixture of hydrogen (H_2), methane gas (CH_4), ammonia gas (NH_3), and water vapor (H_2O).

In those long past days, the climate of the young earth was very hot. But after a time, the earth cooled, some of its gases became liquids, and rains began to fall. Years passed by, the low places on the earth's surface filled with water, and the first seas were formed. Methane and ammonia were dissolved in the waters of these seas. The sea waters also contained mineral salts dissolved out of the rocks by the torrential rains. But as yet there was no life.

According to one theory, before long the methane formed new compounds by reacting with other substances in the early seas. Some of these new compounds were the first carbohydrates, fats, and proteins. Such compounds are nutrients, and they may have become abundant in the sea waters.

Then perhaps giant protein molecules, known as *nucleoproteins* (*new*-kleo-*proh*-teeuns), were developed. They may have been built up due to chance unions of some of the earlier protein molecules. A nucleoprotein molecule is not a living thing, but some nucleoprotein molecules are able to reproduce themselves. Nucleoprotein molecules may have begun to use the nutrient molecules in the ancient seas, and began to multiply. In time, free nutrient molecules may have become scarcer, and the nucleoprotein molecules might have had to compete with one another for a dwindling food supply. Then some of the nucleoprotein molecules may have become grouped together to form viruslike particles, and others may have become grouped together as primitive cells.

About two billion years ago life existed in the seas. The atmosphere had changed or was changing. Primitive organisms preyed upon one another. Some of them developed the habits of parasites, and others became saprophytes. Some cells became food makers. It is important to

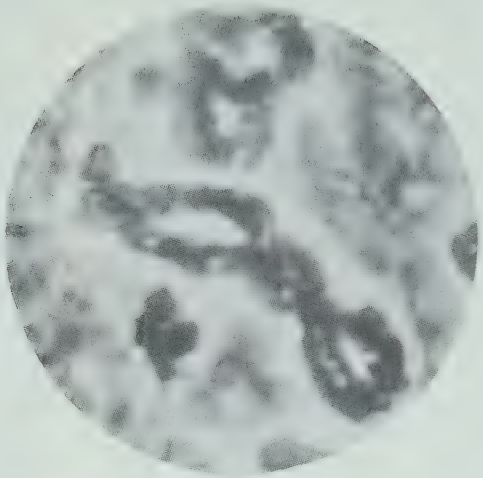
remember that at first all of these organisms were single-celled.

Rocks that were formed about a half billion years ago contain the first fossils of many-celled organisms. Some of these multi-celled organisms were plants, and others were animals. After millions of years, some of their descendants came to live in swamps, and still later they moved out on the land. The first land vetebrates were amphibians that came from fish-like ancestors. Soon thereafter, primitive reptiles developed from a similar ancestry.

About 200 million years ago, the Age of Reptiles began, and lasted about 140 million years. This is the age when dinosaurs roamed the land. But there also were many other kinds of reptiles, both large and small, living in the water and on the land. At this time, some primitive birds and mammals came into existence.

About 60 million years ago, most of the giant reptiles, that had dominated the land for so long, disappeared from the scene. We do not know what caused their rapid decline; perhaps they were victims of disease epidemics; perhaps a changed climate no longer favored their survival. Then came the Age of Mammals, which continues today. The populations of various groups of mammals began to increase. Mammals became the dominant form of life on land. In this setting, manlike forms of life appeared nearly two million years ago.

Block IV is the story of how modern plants and animals reproduce, compete with one another, and survive. How organisms inherit characters from their ancestors, and how new characters are developed will be discussed. Block IV also includes ways in which we use our knowledge to advantage, as we obtain foods and other materials from the plants and animals of our world.



CHAPTER 18

Reproduction and Population

In the complex organism there is division of labor among the cells of the body. But very early in life all cells of the future body are more or less alike. These first cells divide and this makes growth possible. Soon special cells begin to develop, and then tissues, organs, and systems appear. After the adult body has been formed, the production of many kinds of new cells slows down. But even in the adult body, some cells continue to divide. The new cells they produce replace damaged or worn-out cells.

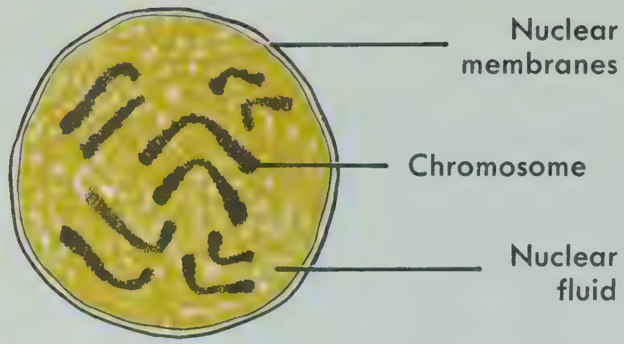
In fact, cell division is necessary for both growth and repair. It also is necessary for the production of offspring. In the more complex organisms, offspring usually have two parents. Each parent contributes a single sex cell to the production of a new individual. When this happens, it is a case of sexual reproduction.

To get a better understanding of growth and reproduction, we must learn some new things about cells. In the following section, you will read about structures in the cell nucleus, and how they behave when the cell divides.

CHROMOSOMES AND GENES

In our earlier studies of cells, we have not discussed the nucleus in detail. We have merely noted that the nucleus appears to be the structure which dominates or controls the cell's activities. We shall now attempt to see how this control operates.

Chromosomes and their genes. Fig. 18–1 shows a diagram of a nucleus. The nucleus contains a nuclear fluid. In the fluid are various bodies called the ***chromosomes*** (*kroh*-moh-sohms). Chromosomes may be threadlike, rodlike, or have a number of other shapes. They are made up of protein molecules and nucleoprotein molecules. The nucleoprotein molecules contain many *DNA* units and some *RNA* units. You have read about the nucleic acids we call *DNA* and *RNA* on page 31. One thing



18–1. A diagram of a cell nucleus.

to remember at this point is that there are many kinds of *DNA* and *RNA*.

A chromosome, in turn, contains a number of ***genes*** (*jeens*). A gene is a small mass of nucleoprotein. As you have learned previously, nucleoproteins are made up of protein molecules that have been combined with nucleic acid molecules. And nucleoproteins are able to reproduce themselves.

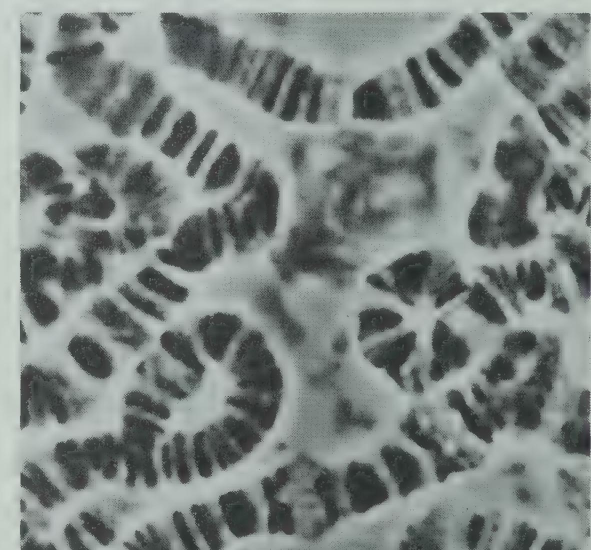
So a particular gene contains one kind of *DNA* combined with protein to form a nucleoprotein. This gene is located in a chromosome in the cell nucleus. Here the gene remains, but it produces *RNA* molecules which move out into the cell's cytoplasm. These *RNA* molecules are patterned after the *DNA* molecules that produced them.

Out in the cytoplasm the *RNA* molecules cause various proteins, including enzymes, to be formed. These proteins are of certain special types in a muscle cell, and other types in a gland cell. So in a very real sense the *DNA* molecules direct cellular development, and determine what kind of cell will result. They do this by producing a group of *RNA* molecules that preside over the formation of the cell's proteins.

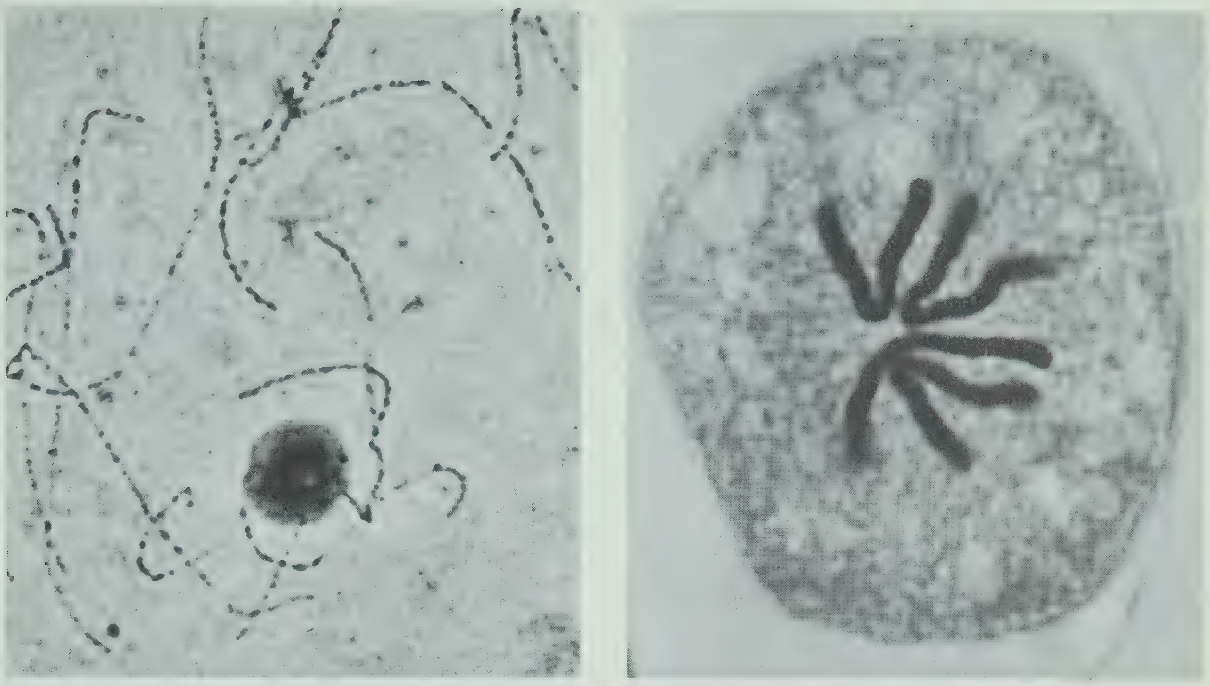
The genes in a sex cell also determine what will be passed on by *heredity*. Heredity is what a cell or an organism inherits from its ancestors. Your eye color is an example of a character that is inherited.

Chromosome pairs and numbers. One of the first things to know about chromosomes is that they are found in pairs. Their number varies from one species to another, but is the same for members of a given species. Thus each cell of a corn plant contains 10 pairs of chromosomes, each cell of a housefly contains 6 pairs of chromosomes, and each human cell contains 23 pairs of chromosomes.

The reason for this pairing of the chromosomes is simple. Let us take a housefly as an example. A housefly develops from a fertilized egg cell. In this egg cell are six chromosomes that came from the male parent, and six chromosomes that came from the female parent. These chromosomes remain separate in the body tissues of the housefly. Each time a tissue cell divides by mitosis, its chromosomes are duplicated;



18–2. The chromosomes of a fruit fly. *(A. M. Winchester, Biol. Dept., Colorado State College, Greeley, Colorado)*



18–3. The chromosomes of a plant and animal. Left, corn; right, ascaris worm. (*Left, Richard Snow, University of California, Davis; right, A. M. Winchester, Biol. Dept., Colorado State College, Greeley, Colorado*)

one full set of chromosomes goes to each of the two new cells that are formed.

Genes also come in pairs. Since the genes are located in the chromosomes, and the chromosomes are found in pairs, the genes come in pairs also. Suppose, for example, that a certain gene determines eye color. This gene will be found in the two chromosomes of a certain pair. The gene in one chromosome has come from the male parent, and the gene in the other chromosome has come from the female parent.

The genes of such a pair may or may not carry the same kind of heredity. Let us suppose that they do; that they both tend to produce a red eye color. In that case, the offspring will have red eyes. But suppose one gene carries a red tendency and the other gene carries a grey tendency. You will learn what is likely to happen when you study Chapter 21. You will also find that a character such as the color of some structure is not always determined by a single pair of genes. Sometimes two or more pairs of genes may influence what the character will be.

MITOSIS

On page 45, you had an introduction to cell division. In the case of some cells, this process is quite simple. In fact, some cells do not have organized nuclei. If these cells have genes, the genes are simply scattered about in the protoplasm of the cells.

In many other cells, however, well-formed nuclei are present, and cell division is more complex. In the process the chromosome materials are divided equally between the two cells that have come from the original parent cell. This type of cell division is called ***mitosis*** (my-*toh*-sus).

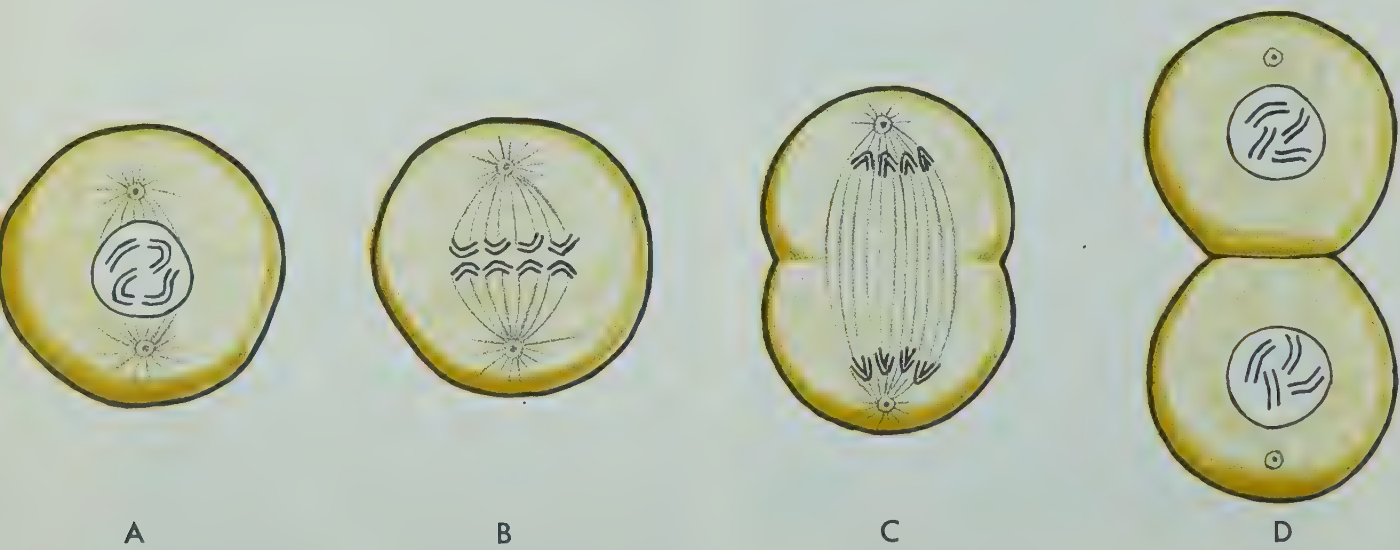
An example of mitosis. An example of mitosis is shown in Fig. 18–4. The cell in this diagram normally contains four pairs of chromosomes. In *A*, the chromosomes have come together, and are actually in the process of duplication. In *B*, the chromosomes have duplicated; now there are two groups of chromosomes with four pairs in each group. One group of chromosomes is moving toward one end of the cell, and the other group is moving toward the opposite end of the cell. In *C*, the two groups of chromosomes have arrived at the opposite ends of the cell, and the cytoplasm is beginning to divide. In *D*, nuclear membranes have formed around the two groups of chromosomes, and division of the cytoplasm is virtually complete.

Each daughter cell produced in this manner has the same pairs of chromosomes that were in the parent cell. Each daughter cell also has the same pairs of genes that were in the parent cell. One difference between the daughter cells and the parent cell is that the daughter cells are smaller. But the daughter cells may soon grow to full size.

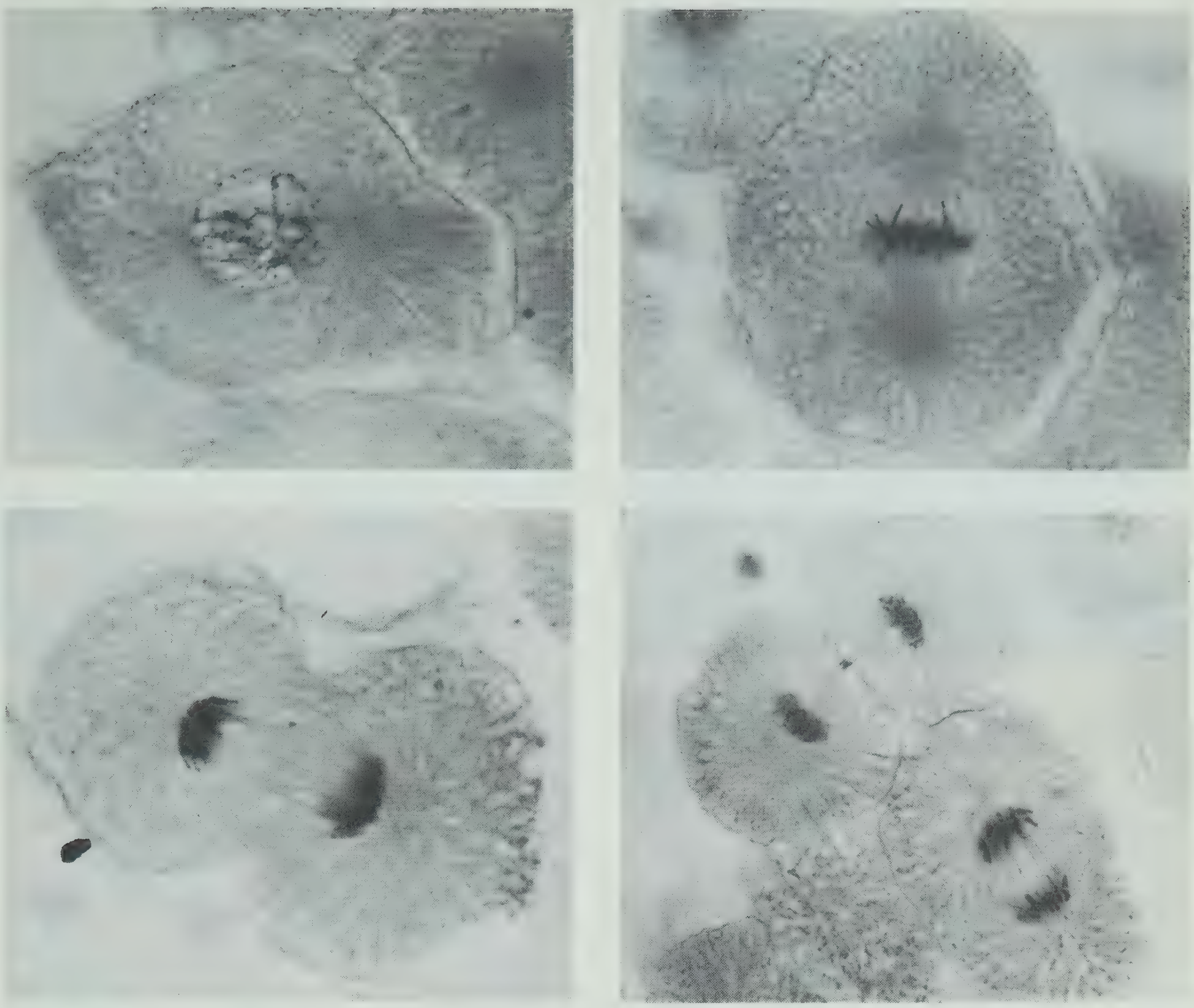
Mitosis, growth, and repair. In the body of a complex plant or animal, the cells of various tissues divide now and then by mitosis. The new cells that are produced make growth possible during early life. New cells are also needed to replace worn-out cells. For instance, you may recall that cells of the outer skin layer die and are constantly sloughed off.

When you suffer even a small cut, new cells must form if the cut is to heal. This process is known as ***regeneration*** (ree-*jenner*-ashun). Some animals have very strong powers of regeneration. If a starfish loses one of its arms, it will soon develop a replacement. Hydra and some of the flatworms are also able to regenerate major parts of their bodies. Among the vertebrates, however, powers of regeneration are not so well developed.

Mitosis and reproduction. The fertilized egg cell of a complex organism also divides by mitosis. So do all of the cells that develop from this egg cell. This is why you find the same pairs of chromosomes in all the cells of an adult body.



18–4. A diagram of mitosis. (A) The chromosomes have come together; (B) the chromosomes have duplicated; (C) the chromosomes are at opposite ends of the cell; (D) two nuclear membranes have been formed.



18–5. Four stages in mitosis. Can you describe what is happening in each stage? (*Courtesy, The Upjohn Company*)

SEX CELLS

In many forms of plant and animal life, including the higher types, reproduction is sexual. This generally means that special groups of cells develop into male sex organs or into female sex organs. In some species, the organs of both sexes are developed by one individual. In other species, the sexes are separate.

Sperm cells and egg cells. The male sex organs or *testes* produce large numbers of *sperm cells.* These sperm cells usually are quite small, and many of them swim about actively in liquids. Despite their small size, the sperm cells contain the same number of chromosomes that are found in egg cells of the same species.

The female sex organs or *ovaries* produce *egg cells.* Generally these egg cells are much larger than the sperm cells, because they contain quantities of stored food. This stored food provides for the early growth of the new individual. Fig. 18–7 shows diagrams of an egg cell and a sperm cell.

The reduction division. The cells of a testis or an ovary, that produce the sex cells, are cells that contain the normal number of chromosomes for the species. By way of example, let us say that this number is two pairs. But when

18–6. A dogfish pup with yolk sac. The young fish is still living on the food stored in the yolk. (*Russ Kinne from Photo Researchers*)

these "normal" cells produce sex cells a change must take place. As the new sperms or egg cells become mature, their chromosome number must be reduced by half. This process is called *reduction division.*

You can see why a reduction division is necessary. In our example, if both the mature sperm and the mature egg contained the normal two pairs of chromosomes, and these two cells

18–7. A diagram of an egg cell and a sperm cell.

united, the resulting cell would have four pairs of chromosomes. It would no longer represent the same kind of organism.

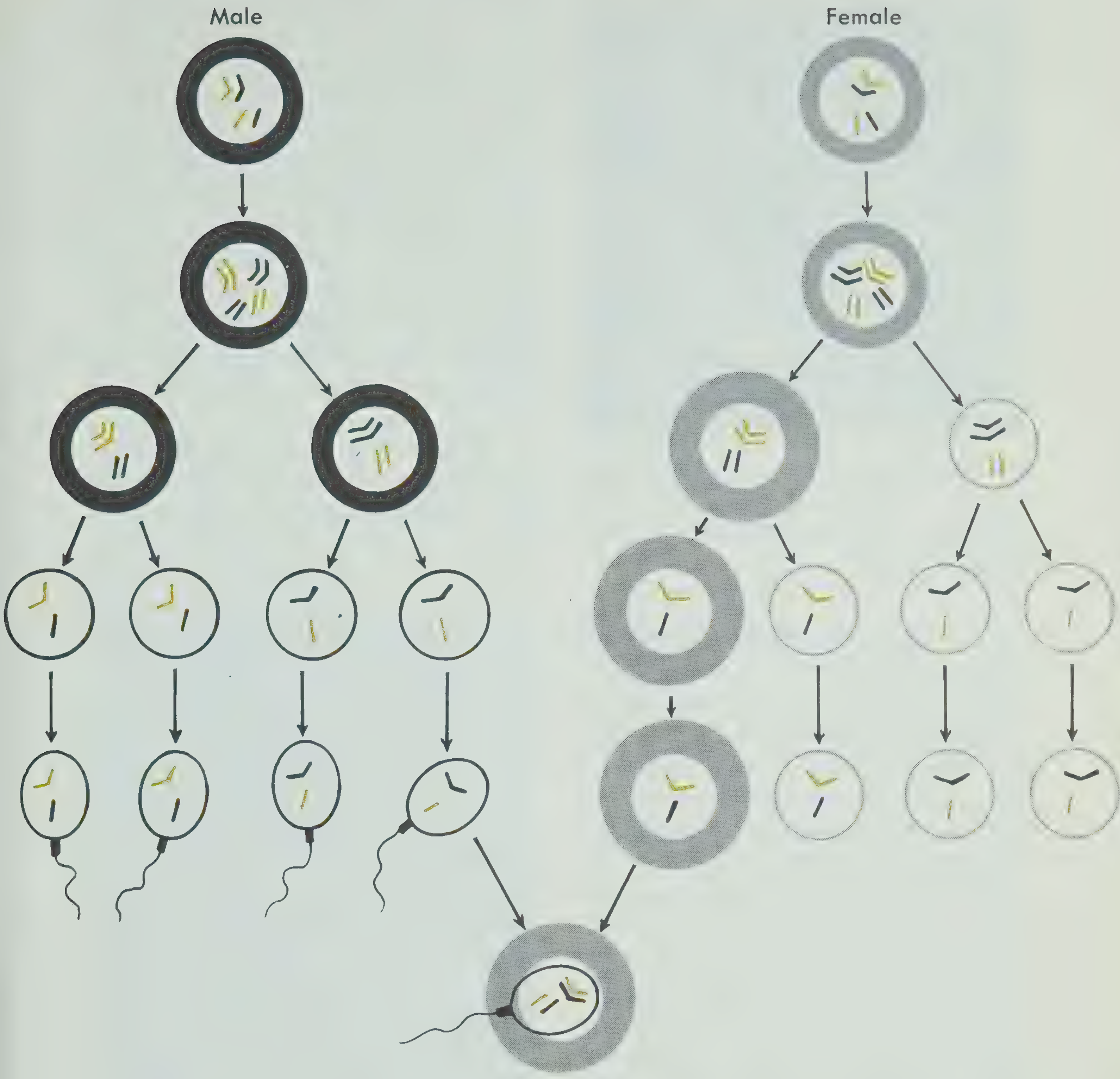
If you examine Fig. 18–8, you can see how the problem of too many chromosomes is disposed of. The two nonmature sex cells have the full number of chromosomes, which is two pairs, in the example we are using. But in the process of becoming mature each cell loses half of its chromosomes.

Mature sex cells. Reduction division is part of the process in which a sex cell becomes mature. This process begins with a nonmature cell in a testis or ovary, and ends with the development of a mature sex cell. The process is called ***meiosis*** (mee-*oh*-sus). It will be easier to understand meiosis if we study an organism that only has two pairs of chromosomes. Refer frequently to Fig. 18–8, as you read the following discussion. Both the male and female sex cells initially contain the normal number of chromosomes for their particular species (two pairs in this case).

A male sex cell first divides by a process similar to mitosis. Its two pairs of chromosomes are duplicated to become four pairs. Then the cell divides into two cells, both containing the "normal" number of chromosomes. (See Fig. 18–8.)

Each of these cells now divides again. But this time, the chromosomes are not duplicated as a first step in the division. So four cells are produced, and each of them contains a single pair of chromosomes. These four cells will develop "tails" and become mature sperm cells.

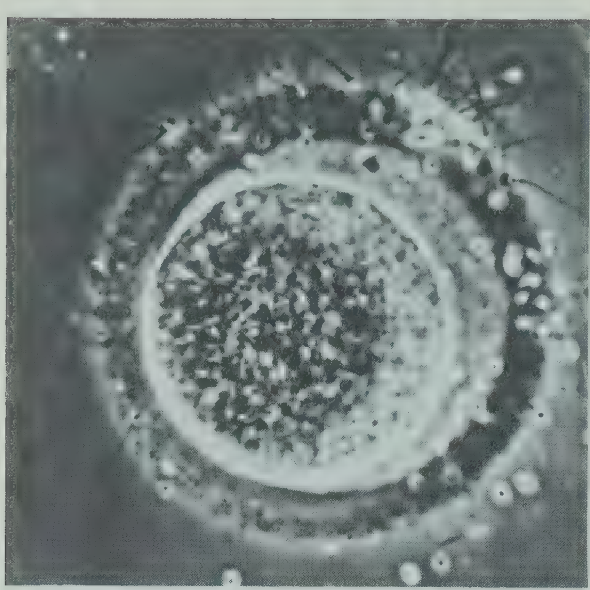
Female sex cells become mature in a similar manner, the only difference being the sizes of the cells produced. In



18–8. Formation of sex cells in an organism with two pairs of chromosomes.

the first division one large cell and one small cell are produced. In the reduction division, one large cell and three small cells are produced. These smaller cells eventually die, and the larger cell becomes the mature egg cell. The mature egg, like the mature sperm, contains half the number of chromosomes for that species.

Fertilization. The union of a mature sperm cell and a mature egg cell is called *fertilization*. An egg cell seems to have a chemical attraction for sperm cells. Sperm cells collect around the outside of an egg cell and attempt to push through the cell membrane. Sooner or later, a sperm cell succeeds, and enters the cytoplasm of the egg



18–9. The living human egg cell at the moment of fertilization. (*Courtesy, L. B. Shettles, Ovum Humanum, Hafner Publishing Co., N.Y.*)

cell. At once, the membrane around the egg cell thickens and becomes harder to penetrate. Now the rest of the sperms are unable to enter.

The nucleus of the egg cell and the nucleus of the sperm cell combine. In our example, each nucleus brought two single chromosomes to this union. The single nucleus that results from their union contains *two pairs* of chromosomes. Do not fail to note that these chromosomes are contributed equally by the male and the female parent. The cell is now a *fertilized egg cell.* The fertilized egg cell contains the "normal" chromosome number for that species. In a favorable environment it can begin to divide, starting the process that leads to development of a new individual.

DEVELOPMENT

The development of organisms, from fertilized egg cells to adults, varies considerably among different species. But there are some ways in which all types of development are similar. For instance, the formation of many cells is always necessary. First, the fertilized egg cell divides to form two cells, by the process of mitosis. These two cells divide to form four cells, and the four cells divide in turn. During the early stages of development, many cells may grow and divide rapidly. But in various species, some of the cells grow and divide more rapidly than other cells do.

At some stage in fairly early development, special types of cells begin to appear. Some of them give rise to blood cells, and others to muscle, nerve, gland, or connective tissue cells. Such cells have become *specialized.* Their nature depends upon the type of *DNA* they contain.

It may seem surprising that a complex body, such as that of a cat, a dog, or a man, can develop from a single cell. But this is exactly what happens. A fertilized egg cell is truly remarkable, because it contains the *DNA* that directs the formation of many tissues, organs, and systems.

Populations. To maintain its normal numbers in the community, any species of organism must have a successful method of reproduction. This means that a certain number of fertilized egg cells must be produced. It also means that the young, which come from the fertilized egg cells, must survive in reasonable numbers and become adults. For adults, of course, are necessary to produce the next generation.

Among many plants and animals, these requirements are met by producing very large numbers of spores, seeds, or eggs. Most of these spores, seeds, and eggs do not give rise to adults. But

enough adults are developed to keep the species in existence.

Consider, for example, the case of a female fish that produces five million eggs a year, starting with the second year of its life, when it becomes mature. Suppose that all of its eggs develop into fish that manage to survive, and that half of the young are males and the other half are females.

We start out with one pair of mature fish in the first year. The female of this pair produces 5 million eggs, which soon hatch. At the end of the year there are 5,000,002 fish. In the second year we still have only one mature female, who produces another 5 million offspring. So at the end of the second year there are 10,000,002 fish.

18–10. To survive, an organism must have a successful method of reproduction. This photograph shows more than one thousand eggs produced by the spadefoot toad. (*Charles E. Mohr from National Audubon Society*)

In the third year, the 2½ million females of the first year's brood are mature and begin to reproduce. Now the population begins to increase "by leaps and bounds." At the end of the third year, the situation is as follows:

1. Offspring produced by 2½ million newly matured females in third year	12,500,000,000,000
2. Offspring produced by the original female in third year	5,000,000
3. Population at end of the second year	10,000,002
Population at end of the third year	12,500,015,000,002

This is more than 12½ trillion fish. The oceans of the world would still hold them, but not after a few more years passed. Fish do not become so numerous, as these figures indicate they might. In nature, the vast majority of fish eggs do not produce new adults. Either the eggs never have a chance to hatch, or the young fish are devoured early in life.

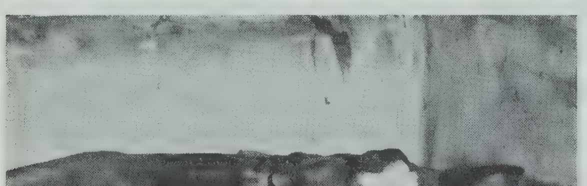
You find a similar example when you consider the vast number of seeds produced each year by a maple tree. To be sure, some of these seeds may be carried a distance from the parent tree by the wind. But even so, there simply is not enough room for the seeds of all maple trees to sprout and to grow. So it is only an occasional seed that gives rise to a new maple tree.

Parental care. Many organisms provide no sort of care for their offspring. For instance, a female fish usually lays her eggs and then swims away. It is

true, however, that some species of fish do lay their eggs on gravelly lake bottoms, and then maintain a sort of guard over them until they are hatched. Also, some female fish bear their young.

How do species continue to exist when their young have little chance to survive? The answer is that these species produce vast numbers of spores, seeds, or eggs. If they did not have this rapid potential rate of reproduction, many of them would soon be extinct.

Among the birds and mammals, we find many species that protect and feed the young until they have grown and can shift for themselves. Such species generally produce only a limited number of offspring. Birds do not lay eggs by the millions, or even thousands, as some of the less complex animals do. Some mammals produce a number of young at each birth, but other mammals produce only one or two young at a time. Nevertheless, birds and mammals continue to exist. This is because a fairly large proportion of their offspring survive. The higher survival rate is made possible by parental care.



18–11. The cow protects and feeds its young. Why do animals like the cow have fewer offspring? (*USDA*)

POTENTIAL POPULATION INCREASE

As examples of how potential rates of increase would affect populations, you can make the following tests. Remember that in this case "potential" means that all fertilized egg cells develop into mature organisms.

SEEDS OF A CORN PLANT Assume that a typical corn plant bears two ears of corn that are about equal in size. Count the number of seeds on one ear of corn. Double this amount to account for the second ear of corn.

Now assume that each corn seed produces a new corn plant, and that each new corn plant produces as many seeds as the original plant did. How many seeds would be produced by this *second generation* of corn plants? How many seeds would be produced by a *third generation?*

DIVISION OF A SINGLE-CELLED ORGANISM Some of the simple, single-celled organisms can grow to full size and divide every 30 minutes. Start with a single cell. Assume that all of its descendants survive and divide every 30 minutes. How many descendants would exist after 24 hours?

ANALYSIS Prepare answers to the following questions in your notebook:

1. If all fertilized egg cells developed into mature plants and animals, what would happen to the populations you have just been studying?
2. What factors of the environment keep populations from realizing their enormous potential for increase?

WORD MEANINGS

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. A chromosome is composed of
   (a) carbohydrate and fat molecules.
   (b) protein, *DNA*, and *RNA* molecules.
   (c) protein and fat molecules.
   (d) protein and carbohydrate molecules.
2. Small hereditary units located in the chromosomes are known as
   (a) testes.
   (b) embryos.
   (c) genes.
   (d) ovaries.
3. If a mature sex cell of species *A* contains four chromosomes, each body cell of species *A* will contain
   (a) two chromosomes.
   (b) four chromosomes.
   (c) eight chromosomes.
   (d) twelve chromosomes.
4. The units in a cell that determine what kinds of *RNA* molecules will be formed are the
   (a) nuclear membranes.
   (b) cytoplasmic granules.
   (c) nuclear fat molecules.
   (d) *DNA* molecules.
5. When two cells divide, so that each daughter cell receives a full set of chromosomes, the process is called
   (a) asexual reproduction.
   (b) simple division.
   (c) mitosis.
   (d) budding.

6. The process in which a nonmature sex cell becomes a mature sex cell is known as
   (a) budding.
   (b) reproduction.
   (c) multiplication.
   (d) meiosis.
7. Mature egg cells are formed from cells of
   (a) an ovary.
   (b) an embryo.
   (c) a spore.
   (d) a testis.
8. If the chromosome number of species *B* is eight pairs, mature egg cells of this species will contain
   (a) four chromosomes.
   (b) eight chromosomes.
   (c) sixteen chromosomes.
   (d) thirty-two chromosomes.
9. The union of a mature egg cell and a mature sperm cell is known as
   (a) fission.
   (b) fertilization.
   (c) meiosis.
   (d) mitosis.
10. Among the simpler animals, the vast majority of eggs
   (a) have hard outer shells.
   (b) are laid on land.
   (c) fail to produce new individuals.
   (d) are fertilized by spores.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Chromosomes contain protein molecules and nucleoprotein molecules.
2. A nucleoprotein molecule may contain *DNA* units or *RNA* units.
3. *DNA* molecules are produced by *RNA* molecules.
4. *DNA* molecules are ordinarily found in the cytoplasms of cells.
5. What a cell can do depends largely upon its genes.
6. In cells of the adult body, chromosomes are in pairs.
7. The number of chromosomes in body cells varies considerably among the members of a species.

8. In meiosis, the number of chromosomes is reduced by half.
9. Only the sex cells of complex animals are able to divide by mitosis.
10. When mitosis occurs, each daughter cell receives the same chromosome material that was in the parent cell.
11. In some species of organisms, both male and female sex cells are developed by the same adult.
12. Sperm cells are generally larger and less active than egg cells.
13. A fertilized egg cell contains the "normal" number of chromosomes for that species.
14. Genes determine the nature of characters that organisms inherit.
15. The body of a fish or dog begins its development as a single fertilized egg cell.
16. To continue in existence, a species must have a successful method of reproduction.
17. In nature, the great majority of plant seeds give rise to new adult plants.
18. You would expect a female fish to produce more eggs than a bird would produce.
19. Mammals usually have a higher potential rate of reproduction than the simpler animals do.
20. In nature, many young plants and animals do not survive long enough to become mature.

DISCUSSION QUESTIONS

1. How does asexual reproduction differ from sexual reproduction? What are some examples of each type?
2. What is the relationship between chromosomes and genes?
3. What functions are carried out by the *DNA* molecules of genes?
4. What is the relationship of *DNA* molecules to *RNA* molecules?
5. What accounts for the fact that chromosomes are paired in the cells of an adult organism?
6. In what ways are genes related to the process of heredity?
7. How is mitosis related to formation of new muscle cells? Gland cells?
8. What is meant by meiosis? Why is this process necessary?
9. What are the steps in the fertilization of an egg cell?
10. In what ways are most types of development similar?
11. How is the success of reproduction related to the survival of a species?
12. How can you explain the fact that so many fertilized egg cells fail to produce new individuals?
13. How is parental care related to the success of reproduction?
14. What would happen to many populations, if organisms reproduced at their full potential rate?

THINGS TO DO

1. Using a microscope slide or living specimens, examine the bud of a hydra. Consult references and find out all you can about this budding process. Be prepared to explain why this is an asexual rather than a sexual type of reproduction.
2. Examine a stained section of an onion root tip under the low and high power of a microscope. Locate and observe cells that are in various stages of mitosis.
3. Fill a tray or large flower pot with loam soil from a garden. Put it on a growing shelf in the laboratory, and see that the soil remains moist, but not wet. Observe the various plants that sprout in this soil, and be prepared to explain why they do so.
4. Collect about a dozen frog eggs along the shore of a pond. Place them in an aquarium, and observe how they develop into tadpoles. Continue your observation of the tadpoles as they grow and change to the adult form.
5. After consulting the references found below, prepare a bulletin board display to illustrate what takes place during meiosis. Indicate also what happens when fertilization occurs. You can use chromosomes of different colors to represent the various pairs.
6. Examine prepared slides of developing starfish or sea urchin eggs, under the low power of a microscope. Locate single egg cells, and early stages of development, in which the new individual consists of 2, 4, 8, 16, and 32 cells.

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CHAPTER 19

Plant Reproduction

Many of the simple plants are single-celled, and reproduce by cell division. Other fairly simple, but many-celled plants produce spores that develop into new plants. To do so, however, the spores must be in places where conditions of life are quite favorable. Spore cells are small and do not contain much stored food. So the plants that come from them must "shift for themselves" almost from the start.

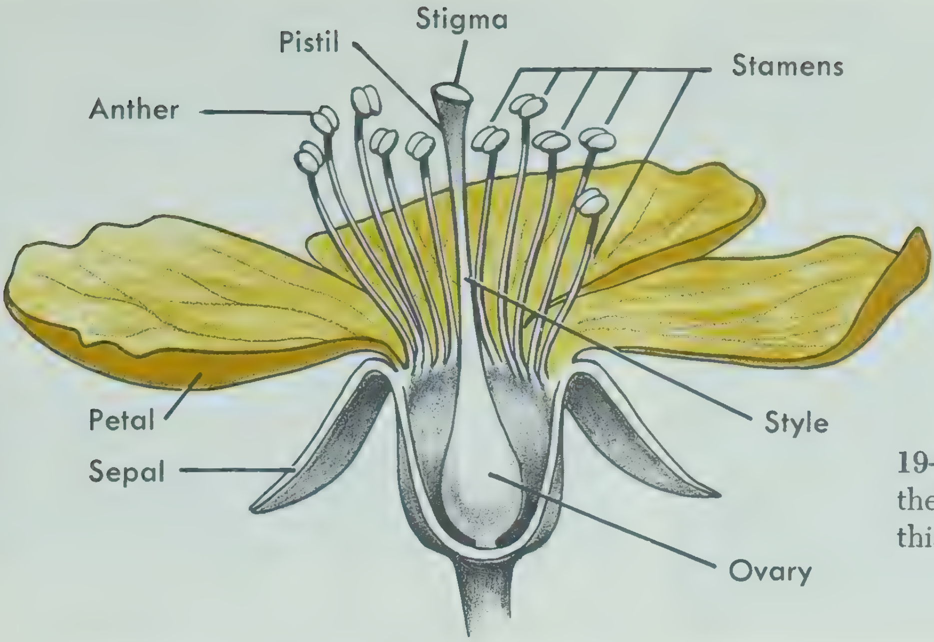
Plants that grow from seeds have one great advantage. The seeds contain stored foods that supply newly sprouted plants with materials for growth. Thus, the young plants have time to become established. They may survive in places where conditions of life are less than ideal. The so-called seed plants reproduce in this way. They are vascular plants, and are the dominant forms of plant life on the land.

You will learn, however, that a good many seed plants can also be reproduced from parts such as roots and stems. In other words, they have two general methods of reproduction. The sexual method involves the development of flowers and seeds; the new plants sprout from the seeds. The asexual method involves growth of the new plant from some part of a parent plant.

FLOWERS, SEEDS, AND FRUITS

All seed plants produce flowers, but some flowers are tiny and not at all like the flowers we raise in our gardens. Only the biologist is likely to recognize that they are basically similar to the familiar lilies, morning glories, and petunias. Seeds are developed from structures of flowers.

Parts of a flower. Fig. 19–1 shows the structures of one kind of flower. Around its base are some green, leaflike parts called ***sepals*** (*sea*-puls). Just inside the ring formed by the sepals are the ***petals*** (*pet*-uls). The petals are the brightly colored parts that make flowers attractive. As you know, some petals are white, and others are red, blue,



19–1. A diagram showing the structures of a flower. Is this a complete flower?

yellow, orange, or various combinations of colors.

Inside the petal ring, a number of ***stamens*** (*stay*-muns) may be found. At the upper ends of the stamens are structures called ***anthers*** (*ann*-thurs). Stamens and their anthers are the male parts of the flower.

In the center of the flower, shown in Fig. 19–1, is the ***pistil*** (*pis*-tul), which is the female part of the flower. At the base of the pistil is a swollen ovary. It is in the ovary that egg cells are produced. From the ovary, a ***style*** (*stile*) extends upward, and bears a ***stigma*** (*stigg*-muh) at its upper end.

You should not think that all flowers are exactly like the one described here. Actually, flowers vary a good deal among different species of plants. Some of them are called *incomplete,* because they lack one or more of the structures

19–2. Identify the structures in this photograph of an apple blossom. (*Hugh Spencer*)

19–3. Skunk cabbage, with an incomplete flower. (*Doug Fulton from Photo Researchers*)

shown in Fig. 19–1. For example, petals may be lacking. Some flowers have pistils but lack stamens; other flowers have stamens, but lack pistils. Some flowers have their petals joined to form a sort of cup. Some flowers are grouped together to form large "heads" as in the case of sunflowers.

Pollen and pollination. *Pollen grains* are formed by the anthers at the upper ends of the stamens. In the pollen grains are cells that can give rise to mature sperm cells.

The egg cells of a flower are developed within the ovary. Mature sperm cells must reach the mature egg cells, if fertilization is to take place. The first step in this process is called ***pollination*** (*pahl*-uh-*nay*-shun). This is the transfer of pollen grains to the stigmas of the pistils. Pollination takes place in various ways, depending upon the particular kind of plant.

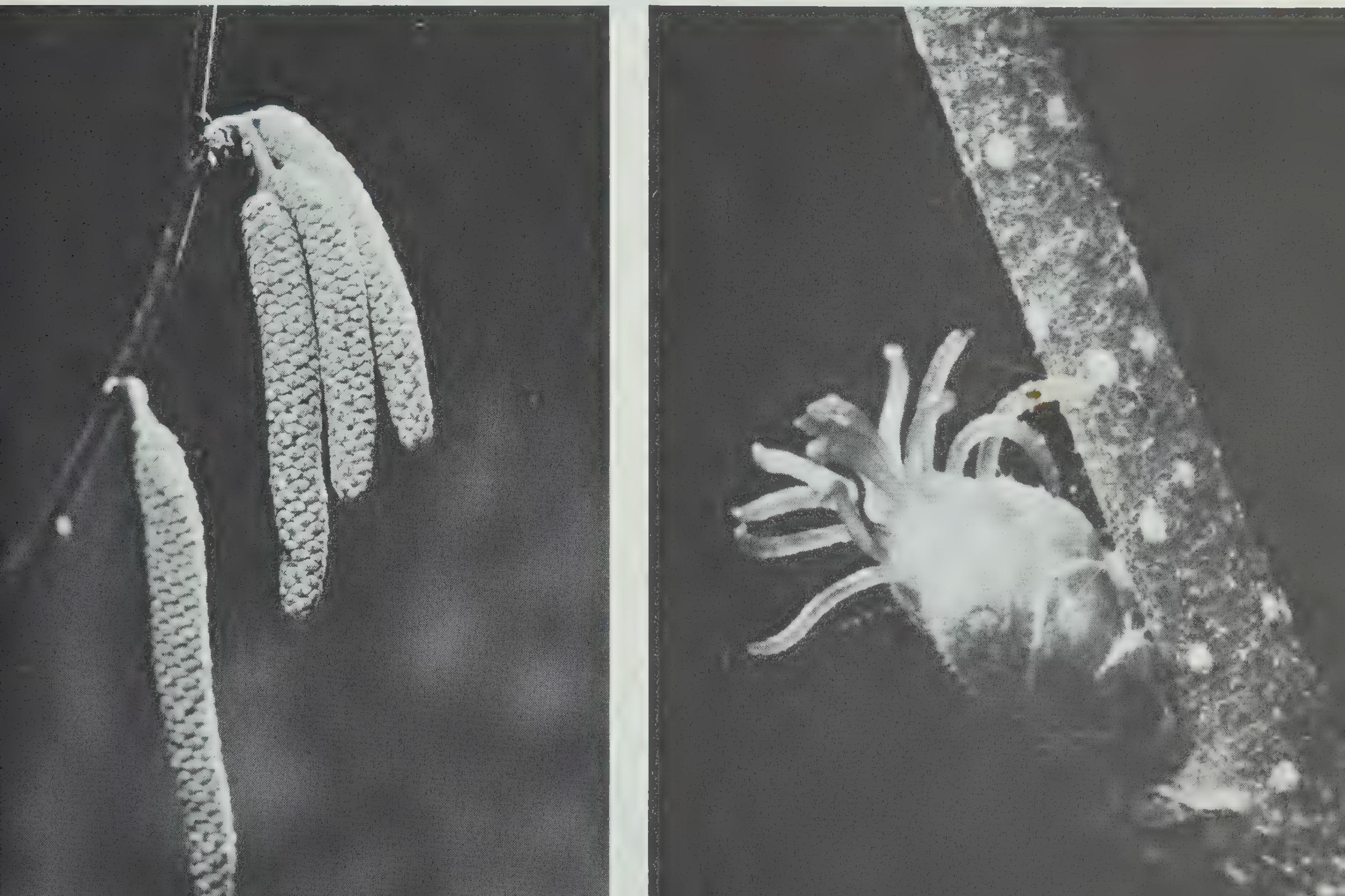
When a flower develops both stamens and a pistil, pollen may simply go from the anthers of the flower to the stigma of the same flower. Such a plant is *self-pollinated.* But in other cases it is necessary for pollen from one flower to go to the stigmas of other flowers. This is called *cross-pollination.* In plant species that have stamens in one group of flowers and pistils in another group of flowers, the flowers must be cross-pollinated. In some species male and female flowers are borne on separate plants. But in other species, flowers have both male and female parts. (See Figs. 19–4 and 19–5.)

Pollen grains are quite small and light, and some of them are carried for great distances by the wind. In early summer many grass plants bloom and the air becomes full of their pollen grains. When some people inhale these grass pollens, they have an allergic reaction. They develop what is sometimes called a "rose cold." In autumn, the air is full of various pollens, and some of them come from ragweed plants. Some people are allergic to ragweed pollens, and develop a condition known as hay fever.

Air-borne pollen is scattered far and wide when certain plants are in flower. Some of the pollen is carried to the stigmas of pistils. Of course, the stigmas must be on the appropriate species of plants. Pollen from an apple blossom will not pollinate a grass plant, and pollen from the grass plant will not pollinate the apple blossom.

Other flowers are pollinated by insects. Among these insects are various kinds of bees. The bees visit the flowers to obtain nectar and pollen. Bees make honey from the nectar, and also use pollen grains as food. Being hairy insects, the bees soon become covered with pollen grains. As they move from flower to flower, they leave pollen

19–4. In the pussy willow, staminate flowers (left) and pistillate flowers (right) are borne on separate plants. (*Hugh Spencer*)



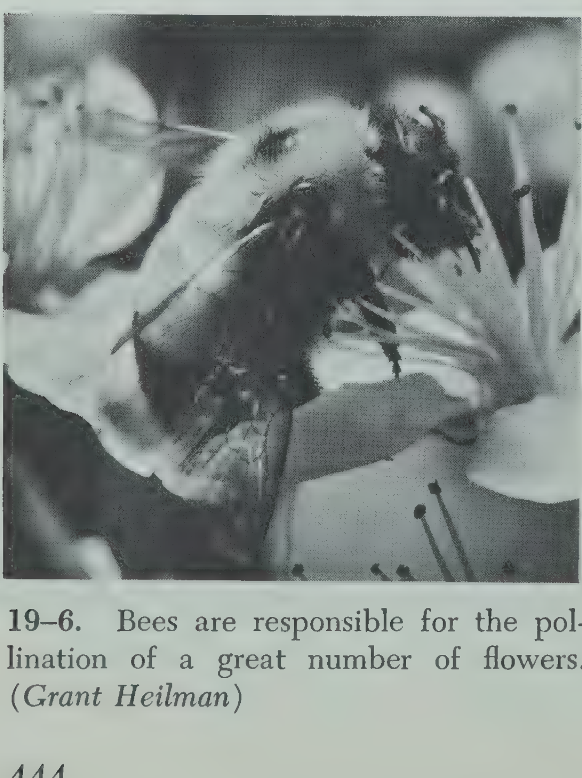
19–5. In the hazelnut, staminate flowers (left) and pistillate flowers (right) are borne on the same plant. (*Hugh Spencer*)

grains along the way. Some of these pollen grains are left on stigmas and pollination takes place.

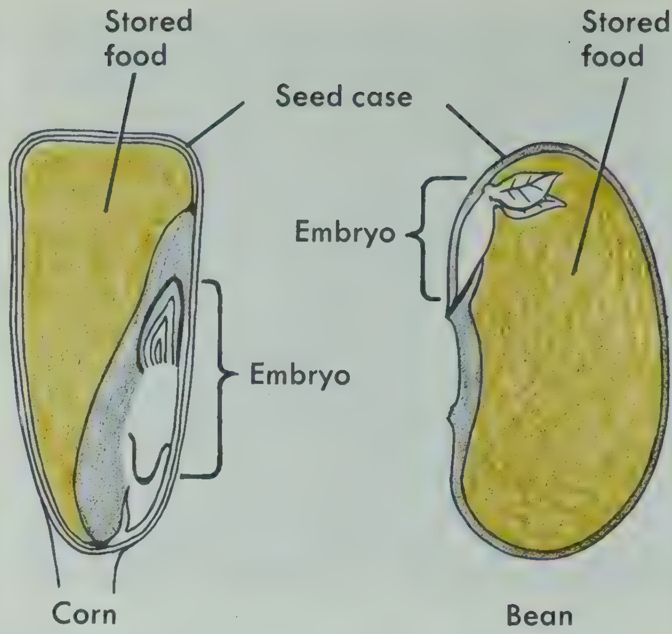
Plants that are insect pollinated are often quite dependent on some particular insect. For example, you cannot raise Smyrna figs unless small fig wasps are present to pollinate the fig flowers. Plants of this type also tend to have rather showy flowers, which may attract the insects. Plants that are wind-pollinated usually have incomplete flowers, that often lack petals.

Fertilization and seed formation. Pollination makes fertilization possible. When a pollen grain is deposited on the stigma of a pistil, it develops into a structure called a ***pollen tube.*** This pollen tube grows down through the pistil, and finally reaches the ovary.

In the pollen tube are mature *sperm nuclei,* which contain half of the normal number of chromosomes. In the ovary is an *egg cell,* which also contains half of the normal chromosome number of the species. A sperm nucleus now unites with the egg cell to produce a fertilized egg cell. The fertilized egg



19–6. Bees are responsible for the pollination of a great number of flowers. (*Grant Heilman*)



19–7. Two common seed types.

cell contains the full number of chromosomes arranged in pairs.

The fertilized egg cell soon begins to divide by mitosis. Before long, it has formed a plant *embryo.* This embryo is enclosed in a seed case, along with stored food. The complete structure is called a ***seed.*** The nature of two common seed types is shown in Fig. 19–7. When the corn seed sprouts, the first part above ground is a stem bearing a single blade or ***seed leaf.*** The bean seedling, on the other hand, has two seed leaves, as you can see in Fig. 19–7.

Seeds and fruits. Fruits are generally developed around the seeds of flowering plants. These fruits are formed largely from the parts of ovaries; some of them are hard fruits, and others are fleshy fruits. You recognize some fruits at once. You know, for example, that an apple is a fruit, and that in its core you will find apple seeds. But some other structures that are fruits to a biologist are not called fruits in the markets.

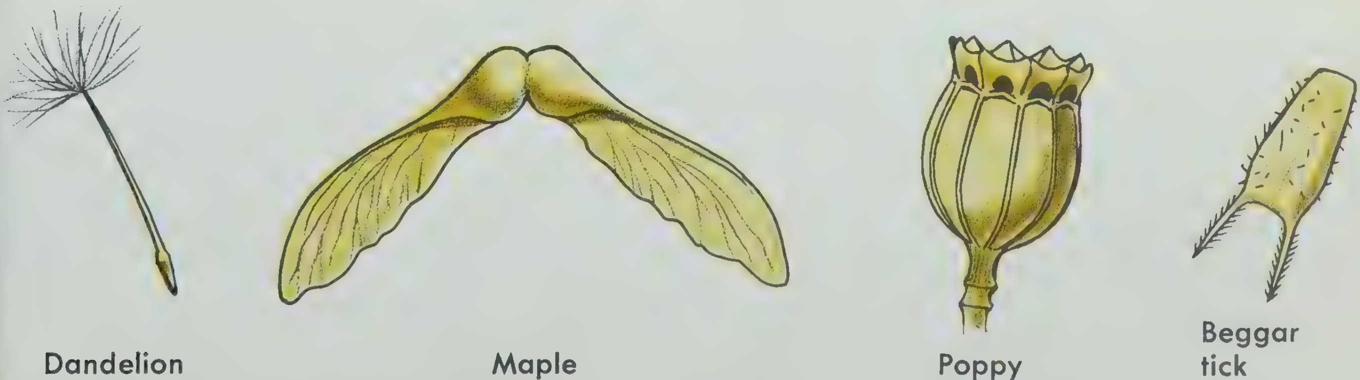
For instance, a pea pod is really a fruit. The pod is the fruit of the pea

19–8. A grouping of fruits. How many of these are called fruits in your local market? (*Grant Heilman*)

plant, and some pea pods, called sugar peas, are commonly used as food. Within the pods are the pea seeds. The tomato you eat in salads is also a fruit, and so are sweet peppers, eggplants, squashes, and string beans. But some fruits are quite different. You would not, for instance, want to eat a cocklebur, even though a cocklebur is a fruit.

Seeds become scattered. Seeds of many types become spread about far from the parent plant. This is an advantage to the species, because young plants must have space and light, if they are to prosper. Too much crowding together would be fatal to many of them. The scattering of seeds is accomplished in a variety of ways, as shown by the diagrams in Fig. 19–9.

The sketches in Fig. 19–9 all show various kinds of plant fruits that have special adaptations. The dandelion fruit, with its attached seed, can be carried long distances by the wind. So can the twin maple fruits, each of which encloses a seed. The poppy fruit is like



19–9. Four types of plant fruits with different seed scattering adaptations.

19–10. A very common way in which seeds are scattered. These black snakeroot seeds are being scattered by a dog. (*John Gerard from National Audubon Society*)

a salt shaker. Near the top are small holes through which the seeds can emerge. As the plant stem is thrust from side to side by gusts of wind, seeds are thrown out in all directions.

The beggar tick fruit, shown in Fig. 19–9, has two clawlike points that will stick to your clothing or the fur of an animal. When any living thing brushes against a beggar tick plant, it is almost sure to pick up some of these clawed fruits and carry them along. Another type of seed transportation involves the berries produced by various plants. These little fruits are eaten by birds and other animals, and later on, the seeds are deposited at some distance from their place of origin. Brooks and streams also serve to transport various seeds that fall into their waters.

Sometimes seeds are carried from place to place in rather surprising ways. In his wanderings across the face of the earth, man has taken weed seeds with him wherever he has gone. This, of course, has not been intentional. The weed seeds have sometimes been in soil around the roots of young trees that are brought to new settlements. Or they have been hidden away in various kinds of farm produce. They may even be found mixed in with the seeds of crop plants.

FLOWER STRUCTURES

You now realize that flowers vary among different species of plants. Some flowers have large colored petals. On the other hand, the flowers of grass plants are without petals.

STUDY OF FLOWER PARTS Select a complete flower to study in detail. First, identify its parts, using Fig. 19–1 as a guide. Carefully remove the sepals, and then the petals. Now examine the stamens, and the pistil (or pistils). Find an anther on a stamen, and a stigma on a pistil. Locate an ovary at the base of a pistil. Remove the ovary, slice it open with a razor blade, and examine the structures within it. If possible, repeat the procedure using one or two other types of flowers.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways were the flowers you studied similar? Different?
2. What parts of the flowers are male structures? Female structures?
3. What kinds of flowers are likely to have brightly colored petals?

POLLEN GRAINS Locate pollen grains on the anther of a flower. Carefully cut off the stamen that bears this anther, and tap off some of the pollen grains into a drop of water on a microscope slide. Cover with a cover glass, and examine your specimens under the low and high power of a microscope.

Repeat this process with other types of flowers. You will find that the shape of pollen grains varies among different plants. All pollen grains, however, are able to develop pollen tubes.

ANALYSIS Prepare answers to the following questions in your notebook:

1. In what ways were the pollen grains you examined similar? Different?
2. What structures of the flower developed the pollen grains?
3. What is the relationship of a pollen grain to a pollen tube?

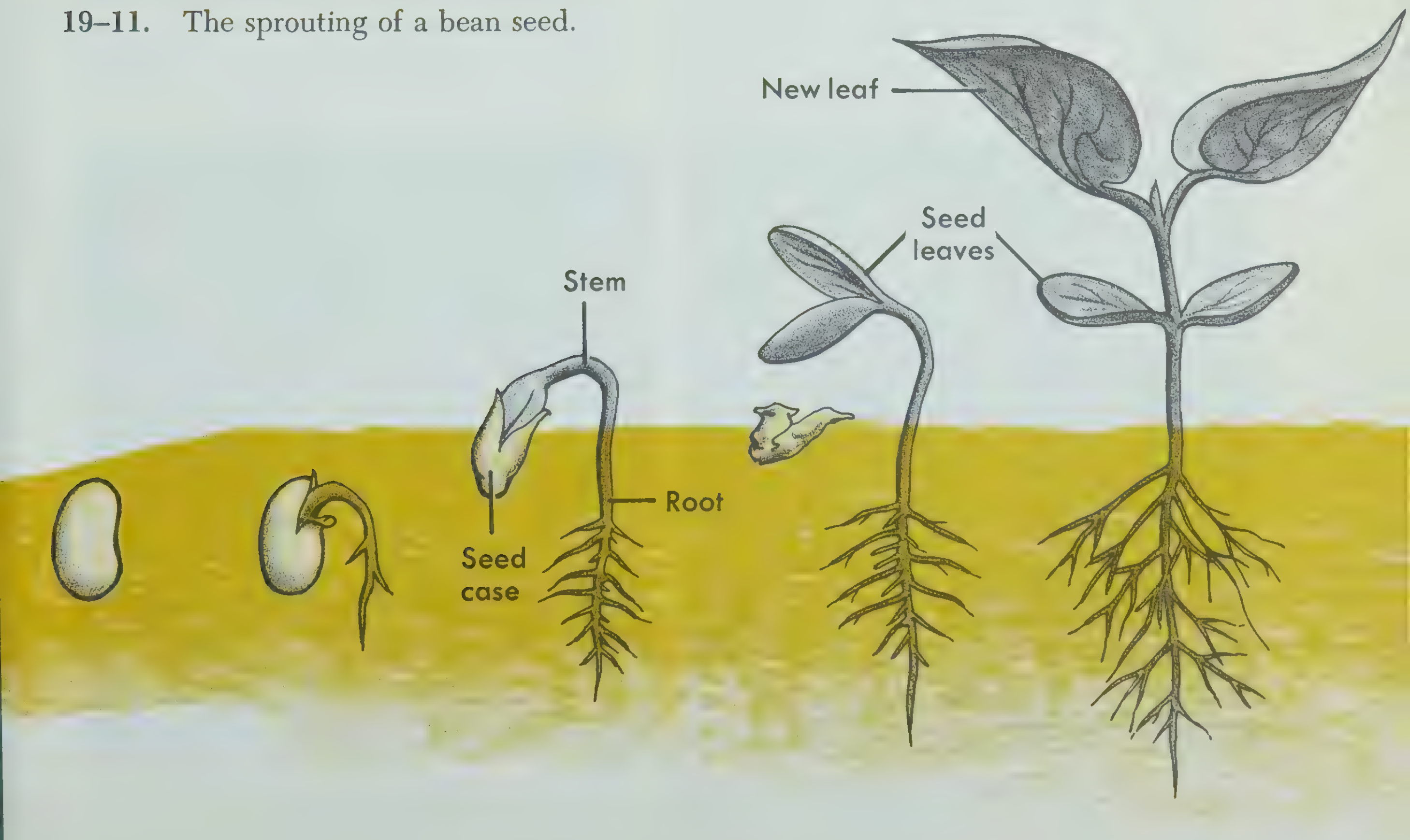
SPROUTING AND GROWTH

The embryo in a seed is in a resting state. Normally, this may continue through the cold months of winter, but when spring comes, conditions may be favorable for sprouting. To sprout successfully, the seed requires proper soil, moisture, and a favorable temperature.

Temperature affects not only sprouting, but growth and survival as well. Some plants are very hardy. They will live in freezing surroundings. But other plants are quickly killed by frosts. Where growing seasons are short and late frosts are likely, the number of crop plants that can be produced is limited.

A bean seed sprouts. The diagrams in Fig. 19–11 show the sprouting and development of a young bean plant. In *A*, the seed is in a suitable place but has not yet sprouted. In *B*, the seed case

19–11. The sprouting of a bean seed.



has split open, and a new growth, that is part future stem and part future root, has appeared. In *C*, the new stem is pushing up through the soil surface, and the two seed leaves are being pulled out of the seed case. In *D*, the two seed leaves are free. In *E*, the young stem is growing upward, and two new leaves have been produced. With these new leaves, the plant is ready to make its own foods.

Notice in Fig. 19–11 that a bean plant is one of the types having two seed leaves. These seed leaves contain stored food and supply the plant with nutrients during early stages of growth. Before the plant is able to make food, two things must happen. First, the plant must develop a root system which can absorb water and dissolved minerals from the soil. Second, the plant must produce leaves that act as food-making centers.

Usually, only a few days are required to complete the early stages of growth. After that, the bean plant is a self-sustaining unit. It must, of course, have a supply of water, carbon dioxide, and the right mineral compounds. It must also receive the energy of sunlight. Given these things and a favorable temperature, a bean plant becomes mature in a few weeks. When it is mature it begins to produce flowers, fruits, and seeds.

Because it has two seed leaves when it sprouts, a bean is called a ***dicot*** (*die*-kot). A corn plant, on the other hand, has a single seed leaf, and is called a ***monocot*** (*mon*-o-kot). The crop plants we raise in gardens and fields, as well as our flowers, are either monocots or dicots. Monocots and dicots make up the two groups of flowering plants.

SEED STRUCTURE

Seeds are alike in that they contain plant embryos and stored food. It is quite easy to study the parts of a large dicot, seed such as a lima bean.

19–12. Left, corn, a monocot; right, bean plant, a dicot. (*Grant Heilman*)

STRUCTURES OF A LIMA BEAN SEED Soak some dried lima beans in water overnight. Dry one of the seeds with paper toweling. Use a pin point to cut through the seed coat, along one edge of the bean. Remove the seed coat.

Within the seed are two fleshy halves that will become the seed leaves when the plant sprouts. Use a pin point to separate these seed leaves, and fold them back in the same way you would open a book. Between the seed leaves, you will find the rather small part of the embryo that produces the root system and stem together with the leaves.

ANALYSIS Prepare answers to the following questions in your notebook:

1. What parts make up the embryo within this seed?
2. How would you expect the seed of a monocot plant to be different?
3. What do you think the function of the seed coat may be?

GROWTH FROM PARTS

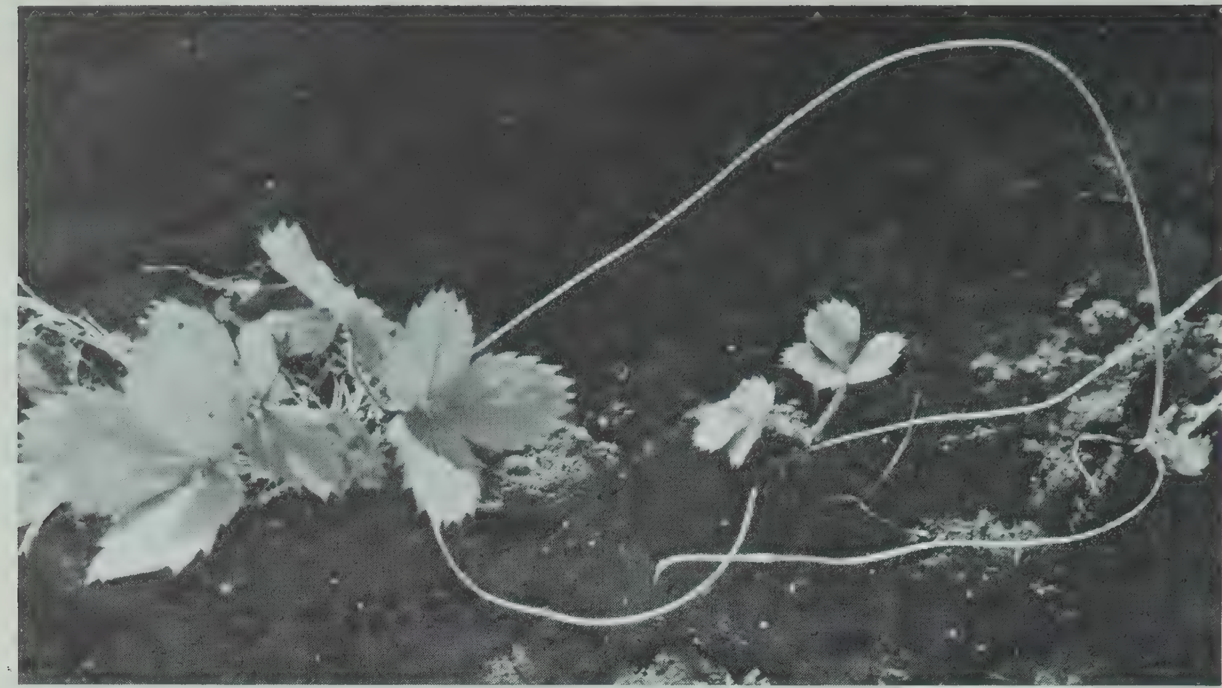
Various higher plants, including some that we raise for food, have the ability to grow from parts. The common white or Irish potato will serve as an example. Normally, this plant is a biennial, which means that its life cycle extends through two growing seasons. It only produces seeds at the end of the second season.

White potatoes and their tubers. Although white potatoes may be raised from seed, there is a much faster way to obtain a potato crop. The potato that you eat is a ***tuber*** (*too*-ber), which is an enlarged part of an underground stem. Here and there on the tuber are "eyes," or spots where buds will develop. All you have to do to grow new potato plants is to plant tubers or pieces of tubers. Each piece or cutting should, of course, have one of the "eyes" on its surface. Potatoes have good ability to grow from parts, and new plants soon develop. Potato plants produced in this manner are in the second year of their normal life cycle.

19–13. Potato "eyes" are necessary for growing potatoes from pieces of their tubers. (*Grant Heilman*)

Reproduction of this type is asexual. From our point of view, it has certain advantages. For one thing, you often get a crop sooner than you would if you depended upon seeds. Also, growth from parts involves only one parent plant. The new plant has the same heredity as the parent plant. If the parent plant was a superior type, the new plant will also be superior.

Other plants that grow from parts. Tulips are among our common flowers. They grow from underground bulbs. New bulbs form on the sides of older bulbs during the growing season. Each new bulb is capable of producing another tulip plant. Other flower-bearing plants that we produce from underground parts include lilies of many



19–14. Strawberry plants may reproduce by lateral runners or stems that take root and produce new plants. (*Hugh Spencer*)

types, begonias, daffodils, and gladioli.

Most varieties of strawberry plants develop lateral runners or stems that are near the soil surface. These runners take root and new strawberry plants develop. A young shoot from a willow tree can be planted in moist soil, where it will take root and become a new willow tree in time. A cutting from a geranium stem can usually be rooted successfully. Some plants can even be reproduced from leaves.

Unfortunately, a good many weed pests can also grow from parts. Crab grass, for example, can develop from small underground parts that have been broken up when a garden is hoed or plowed. As a result, the garden must soon be cultivated all over again. Wild morning glory and poison ivy are other plant pests that can grow from pieces of underground parts.

On the other hand, many of the perennial grass plants, which are generally useful to us, tend to cover bare areas of soil, because they too can grow from parts. Thus, a hillside that has a few grass plants on it may become covered with grasses in time. Roots of the grass plants tend to hold the soil in place and prevent erosion.

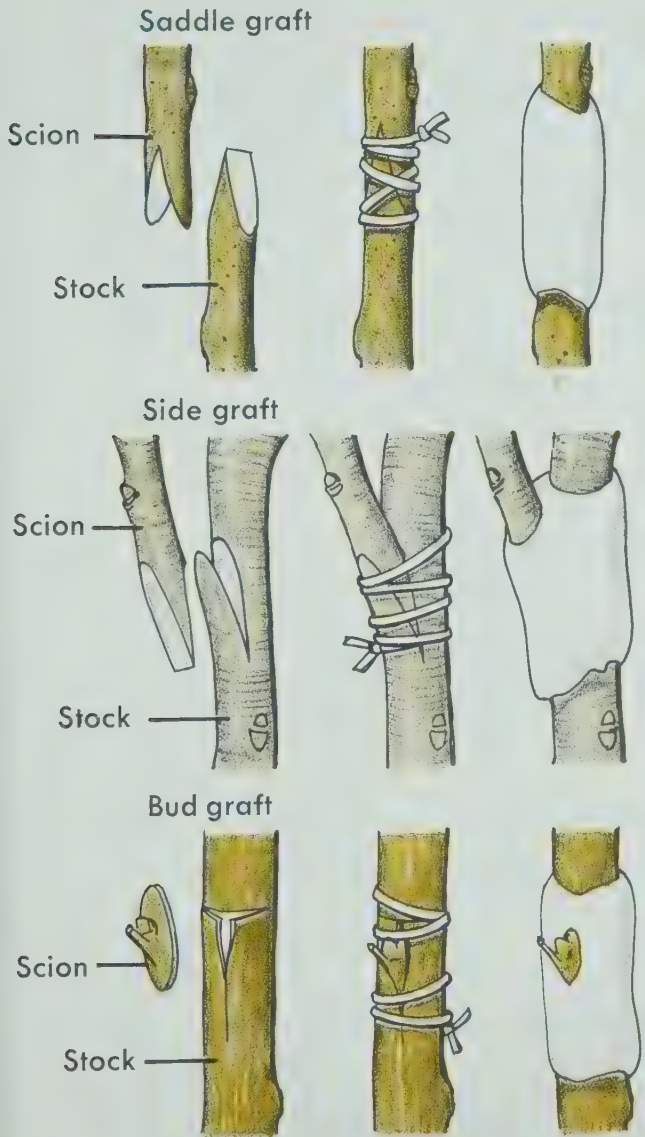
Growth from parts is a natural process among many useful plants. It goes on all the time in the fields and forests. In some cases, the new plants spring up from roots, bulbs, or other underground parts. In other species, runners or stems become rooted to produce the new plants. We take advantage of the natural ability of some plants to reproduce in this fashion, when we raise such things as potatoes, sugar cane, bananas, and some flowers. Like potatoes, banana plants can be grown from pieces of underground stems. The sugar cane plant is produced from stem cuttings. Pineapple plants often are started from shoots called "suckers."

Like animals, plants contain substances that are sometimes called hormones. The effect of these plant hormones is to speed up growth in some

cases, and to slow it down in others. Certain growth stimulators of this type are now extracted from plants and can be purchased in the markets. Using them makes it possible to induce plant parts to form roots and grow in cases where failures might otherwise occur.

GRAFTING

Grafting is another way in which we utilize the ability of many plants to grow from parts. Most of our better fruit trees are the products of the grafting process.



19–15. Techniques that are commonly used in grafting.

19–16. Grafting of a chinchona tree. What kind of a graft is being made in this photograph? (*USDA*)

Grafting techniques. In grafting, you start with the rooted stem of some species such as the apple tree. This rooted stem is called the ***stock.*** On it, you graft a piece of apple stem that comes from a tree known to produce superior fruit. This piece of stem, that you graft on, is called the ***scion*** (*si*-un). If the graft is successful, the resulting tree will produce the desired apples.

Fig. 19–15 shows techniques that are often used in grafting. The cambium layers of the scion and stock must be matched together rather carefully. The graft is wrapped to hold the scion and stock in place, and the area is covered with grafting wax. The wax serves to keep out fungi, that might cause infections, and prevents drying of the tissues before the scion has a chance to grow in place.

Note in Fig. 19–15 that buds as well as stems can be used as the scions. In fact, it is possible to graft several kinds of scions on a single stock. The result may be a tree that produces several varieties of apples.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column. Write in the best statement from the second column for each word.

1. stamen	Fleshy enlargement of an underground stem.
2. pistil	Stem that is grafted on a stock.
3. monocot	Devolops anther at its tip.
4. scion	Bears a stigma at its tip.
5. tuber	Develops a single seed leaf.
6. ovary	Contains sperm nuclei.
7. pollen tube	Develops mature egg cells.

Select the best answer to complete each of the following statements. Write the completed statements in your notebook.

1. The structure which contains a plant embryo is a
   (a) stamen. (c) seed.
   (b) pollen tube. (d) sepal.
2. The structure which is part of a pistil is a
   (a) style. (c) petal.
   (b) anther. (d) scion.
3. A plant fruit is developed from parts of
   (a) a stigma. (c) a pollen tube.
   (b) petals. (d) an ovary.
4. To a biologist, a pea pod with its enclosed seeds is a
   (a) tuber. (c) ovary.
   (b) fruit. (d) bulb.
5. A flower which has no petals could properly be called
   (a) asexual. (c) dependent.
   (b) incomplete. (d) self-pollinating.
6. A young plant which has two seed leaves is a
   (a) dicot. (c) style.
   (b) scion. (d) runner.
7. A pollen tube develops from a(n)
   (a) stigma. (c) sepal.
   (b) ovary. (d) pollen grain.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement.

1. Spores are usually fairly large, and contain a good deal of stored food.
2. Some seed plants can be reproduced from parts of roots or stems.
3. Some flowers have petals, and other flowers do not have petals.
4. Anthers are structures that develop at the upper ends of pistils.
5. All flowers develop both stamens and pistils.
6. The ovary of a flower is located at the lower end of the pistil.
7. Flowers that are wind-pollinated are likely to be incomplete.
8. Pollen grains are developed from parts of a plant ovary.
9. Hay fever may be caused by inhaling the pollen of goldenrod plants.
10. In cross-pollination, pollen from the anthers of one flower is conveyed to the stigmas of other flowers.
11. A pollen tube is developed from a pollen grain that has reached the right kind of stigma.
12. If a mature sperm nucleus contains six chromosomes, a fertilized egg of the same species will also contain six chromosomes.
13. Seeds of flowering plants contain plant embryos and stored foods.
14. A newly sprouted monocot plant has two seed leaves.
15. Some fruits are dry and hard, but other fruits are fleshy.
16. Fruits are developed from fleshy parts of stamens.
17. White potatoes are generally produced by planting their seeds.
18. Some plants can be reproduced from underground parts such as bulbs or tubers.
19. A new plant, which develops from a cutting, has only one parent plant.
20. When a fruit tree scion is grafted on a stock, the stock is the part that will eventually produce the fruit.

DISCUSSION QUESTIONS

1. Why does growth from parts represent asexual reproduction, whereas growth from seeds represents sexual reproduction?
2. Which is more likely to produce a new plant: a seed or a spore? Why do you think so?
3. What parts of a flower produce pollen grains? Why are these parts considered to be male structures?
4. Where are the egg cells of a flower produced? Do all flowers produce these egg cells?
5. Which is more likely to have incomplete flowers: a species that is wind-pollinated, or a species that is insect-pollinated? Why do you think so?
6. What are bees seeking when they visit flowers? Why are these visits of benefit to the plants?
7. Could a plant whose flowers contain pistils but no stamens be self-pollinated? Explain.

8. How does a pollen tube reach an ovary and bring about fertilization?
9. How does a seed develop, and of what does it consist?
10. What is the relationship between seeds and fruits? How are fruits developed?
11. Why do fruits serve to produce widespread scattering of seeds?
12. Why is it an advantage to a plant species to have its seeds scattered widely?
13. In what ways does man bring about a scattering of plant seeds?
14. What is one obvious difference between a young monocot plant and a young dicot plant?
15. What conditions favor seed sprouting and the growth of young plants?
16. Why do we raise potatoes from cuttings, but raise radishes and carrots from seeds?
17. What is the advantage in raising various plants from cuttings?
18. Name some plants that can be raised from underground parts? From stems?
19. How would it be possible to produce an apple tree that would bear several varieties of apples?

THINGS TO DO

1. After consulting some of the references on page 455, prepare a bulletin-board display to illustrate variation among different types of flowers. Label all of the important flower parts in each case.
2. Sprout some bean seeds in one growing tray and some corn seeds in another. Compare the results when the plants first appear above ground and three days later. Remember that beans are dicots, and corn is a monocot.
3. Put two dozen bean, corn, or radish seeds on a cotton surface in a tray. Keep enough water in the tray, so that the cotton remains wet. Observe the sprouting of the seeds for a period of about a week. Do they all sprout at the same time? Do any of them fail to sprout? Be prepared to explain the variations you may observe.
4. Pull up several kinds of weeds. Cut their underground parts into pieces two or three inches long. Plant these pieces under an inch of loam soil which you keep moist but not wet. See if any of the weeds you have selected begin to grow from the underground parts.
5. Put a sweet potato in a culture bowl or other container located on a growing shelf. Keep the container supplied with water from day to day, so that only the upper half of the potato is exposed. Watch for buds and vines to develop. Do not give up too soon; it may be about three weeks before you begin to get results.

6. Remove a slip or cutting from a geranium, and plant it in a sandy, loam soil. Probably the cutting will lose all of its leaves in a day or two, but new leaf buds will soon appear. Keep the soil quite moist for two or three weeks. Observe whether the cutting develops any roots at its lower end.
7. Learn how to make a saddle graft, as shown in Fig. 19–15. Use any green shoot about a quarter of an inch in thickness. Remember that the growing layer of the scion must lie next to the growing layer of the stock. This growing layer is just beneath the outer bark.
8. Obtain some gibberellin, in the form of a salve, from a supply house. Gibberellin acts as a plant growth stimulant. It is easy to coat the stems or leaves of a plant with the salve. Plan an experiment to test the effects of gibberellin upon newly sprouted bean plants. If your teacher approves the plan, carry out the experiment.

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CHAPTER 20

Animal Reproduction

Many examples of both sexual and asexual reproduction are found among animals. Like various plants, some animal species employ both asexual and sexual methods in producing their offspring. Animals also exhibit a variety of striking adaptations of structure and behavior that are associated with reproduction. You have read about some of them on pages 212 to 214. Others are dealt with in the following discussion.

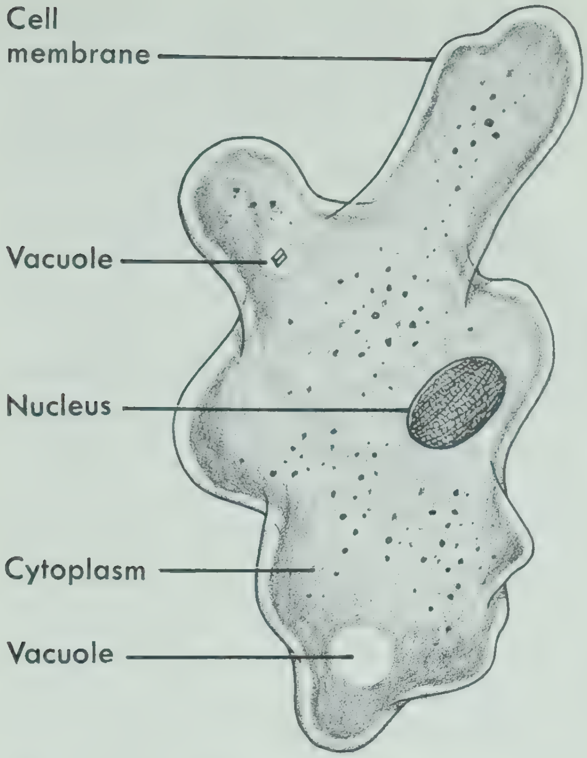
REPRODUCTION BY INVERTEBRATES

Some of the simplest organisms make up the group of protozoa. But do not think that all protozoa are equally simple in their structure or their behavior. Some species are a good deal more complex than others. Many protozoa live as single cells, but there are some types that form colonies of cells.

An ameba divides. You have already learned how a single-celled organism, like a paramecium, divides to form two cells (see page 48). Another organism that is often studied in biology classes is the ameba. Like paramecium, an ameba may be found in fresh-water ponds and streams. Ameba, however, seems to require water that is reasonably clean and cool.

As may be seen in Fig. 20–1, an ameba is surrounded by a cell membrane. This makes it possible for the little organism to change shape readily. This is the same ability that is possessed by the white cells of your blood. You can also see in Fig. 20–1, that an ameba has a nucleus, a cytoplasm, and one or more vacuoles. Vacuoles either contain excess liquid, or food particles that are being digested. An ameba does not swim about like a paramecium. Rather, an ameba flows over various solid surfaces in the water.

An ameba takes food, grows, and then divides to form two new cells. The ameba divides by a simple type of mitosis, as shown in Fig. 20–2. One of its relatives, belonging to the species *Chaos chaos*, is a sort of giant ameba.



20–1. A diagram of an ameba.

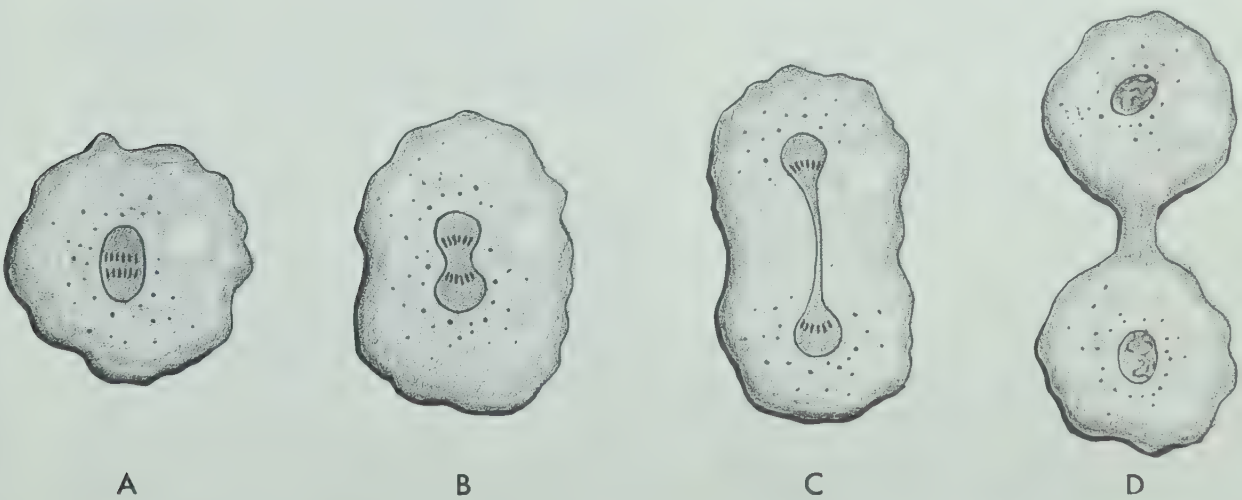
When *Chaos* divides, it usually produces three daughter cells. *Chaos* is another freshwater species, but some related species live in the sea, in damp soil, and as parasites in the bodies of other organisms.

Cyst and spore formation. Ameba and some of its relatives are known to form cysts from time to time. While they are in the cysts, some of them may divide to form two, four, or eight daughter cells. When they first break out of the cysts, these daughter cells are tiny, and might be described as spores.

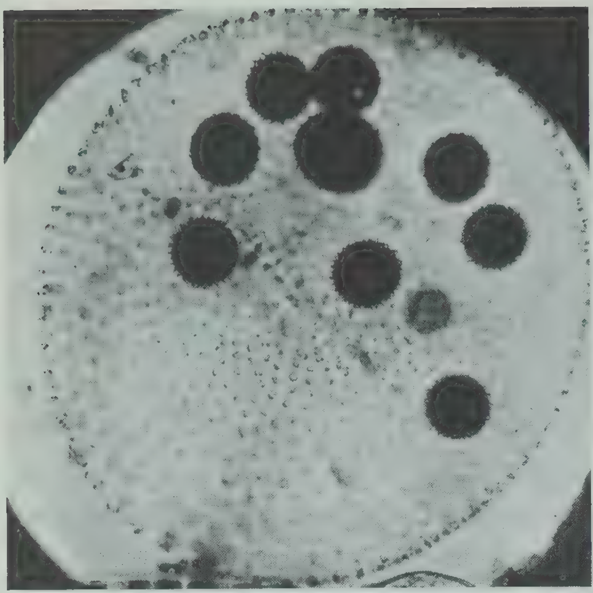
Spore formation is, in fact, a common enough type of reproduction among protozoa. For example, the little protozoan parasites, that cause malaria, spend part of their life cycle in the stomachs of mosquitoes, as described on page 387. While in the mosquitoes' stomachs, these malaria germs develop vast numbers of very small, sporelike cells. As many as a half million of these special spores may be formed in a single mosquito's stomach. When an infected mosquito bites you, it is these tiny spore cells that enter your blood.

Sex cells and somatic cells. One interesting type of organism found in fresh water is called *Volvox.* Some biologists have argued that it is a plant, but other biologists have described it as an animal. Perhaps it should be classified as a protist. This organism lives as a colony of cells that form a hollow ball. Several thousand cells make up such a colony.

The cells of a volvox colony are of two general types. First, there are *so-*



20–2. Mitosis in an ameba. Describe what is happening in each step.



20–3. Photograph of a *Volvox* colony. (*Walter Dawn*)

matic (soh-*mattik*) or *body cells*, which make up the great bulk of the colony, and are all very similar. These somatic cells are not specialized to form tissues; they cannot reproduce to form new colonies. Reproduction depends upon special *sex cells*, which are far less numerous than the somatic cells. Some of these sex cells develop into egg cells, and others produce sperms. The egg cells are fertilized by the sperms, and each of them has the capacity to develop into a new colony.

Reproduction among sponges and corals. The sponges and corals make up two major groups of animals. The members of both groups live largely in the sea, although a few species are found in fresh waters. In both groups, some species live as single individuals, and other species develop colonies, which in some cases are quite large. Coral and sponge colonies are generally attached firmly to some solid object in the water.

Hydra is a member of the coral group, and has been described on pages 67–71. It lives as a single individual. You have learned that hydra develops special sex cells and has a sexual method of reproduction. But it also reproduces by a budding process, as described on page 70. In addition, hydra has strong powers of regeneration.

Sponges and corals generally follow the pattern of reproduction found in hydra. Individual sponges and corals produce both sperm and egg cells. Sperms fertilize the egg cells, and free-swimming embryos are developed. Sponges and corals that form colonies do so by producing buds that remain attached to the parents. This, of course, is an asexual phase of reproduction.

Like hydra, various sponges have good powers of regeneration. In fact, it has been possible to raise sponges for the market by growing them from cuttings taken from sponge colonies. The cuttings are "planted" at a suitable spot on the bottom of the shallow sea. If all goes well, they soon produce new sponge colonies.

Reproduction by flatworms and roundworms. As you have learned, the flatworms and the roundworms include

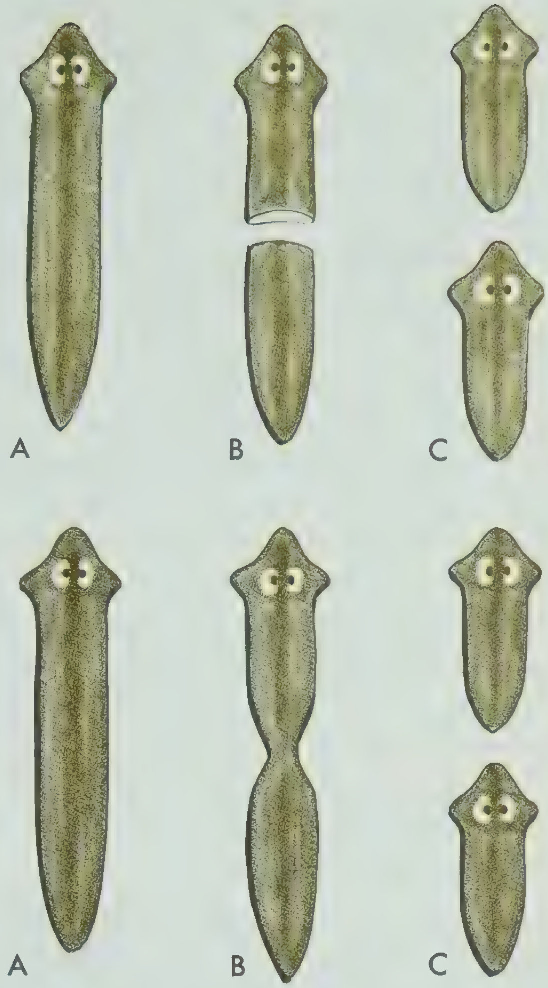
20–4. The raker in this photograph is used to harvest sponges in shallow water. This sponge is attached to a rock base. (*Sponge and Chamois Institute*)

various parasitic types, and other species that lead free lives. Some of the parasites require more than one host to complete their life cycles. One of these parasites begins its life cycle in a snail, lives next on a blade of grass at the water's edge, and completes its life cycle in the liver of a sheep.

One of the free-living flatworms, called planaria, lives in clear, cold streams and ponds. It is a small animal with two eyespots on the upper side of its head. One species of planaria is noted for its ability to regenerate. If it is cut in two, both the head end and the tail end may survive and form complete animals. This is not surprising, for in this species reproduction usually takes place as shown in the bottom half of Fig. 20–5. The body divides through the short axis, and the former tail end develops a new head. Other species of planaria usually reproduce by forming male and female sex cells.

In fact, most species of flatworms and roundworms develop testes and ovaries. In the flatworms, the organs of both sexes are generally in one individual. In roundworms, however, the sexes are usually separate. In some cases, such as the trichina worm you read about on page 369, the eggs develop into embryos before they leave the body of the parent. In other species, the eggs are only partly developed, or not developed at all when they leave the body of the parent.

The rate at which some of the flatworms and roundworms produce eggs is really astonishing. One type of tapeworm, lodged in the intestine of its host, is able to produce about 250 million eggs per year, and may keep on doing so for a period of years. One type of female roundworm may have over 25 million eggs in its body at a given time.



20–5. Top, regeneration in planaria; bottom, reproduction in planaria. How do these two processes differ?

A female hookworm, which is another roundworm, may produce over 35 million eggs in its lifetime.

Earthworm reproduction. Earthworms, like planaria, have good ability to regenerate. This ability, however, has certain limits. As you may remember, some of the important internal organs are located near the head end of an earthworm. If the body is cut in two, halfway between the head and the tail end, these organs will be in the head portion. This head portion is likely to survive, and after a time, it may begin to form new tail segments. The tail portion may live for a few days, but in the end it will die.

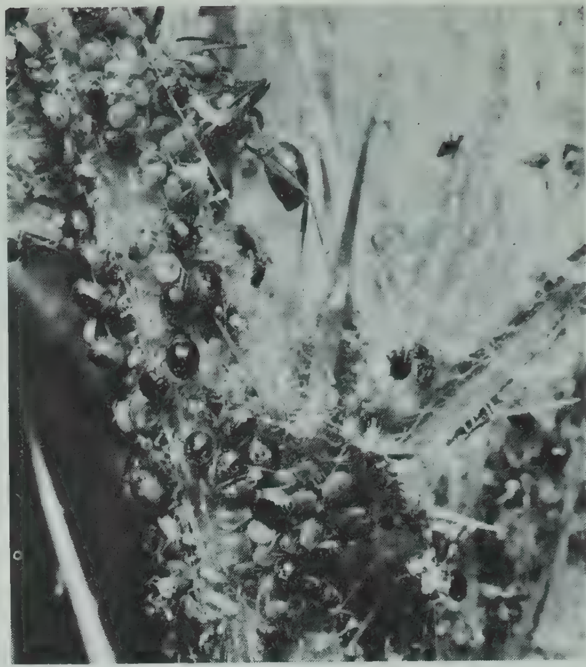
An oyster and its eggs. A female oyster may produce about 9 million eggs in a single season. Male oysters produce sperms at the same time that females are producing eggs. These eggs and sperms are simply discharged into the surrounding water. In the water, some of the sperms find eggs and fertilize them.

Fertilized oyster eggs soon develop into embryos that are covered with cilia. These little embryos swim about near the surface of the water for a period of time. A good many of them are eaten, or meet death in other ways. At a certain point in development, the survivors drop to the bottom and begin to form shells. These shells are attached to solid objects in the water. Thereafter, the oysters are unable to move about. Many of them are smothered by shifting sands and mud.

The story of oysters is like that of many other invertebrates. Millions of eggs are produced each summer, but only a very small number of the eggs develop into adults. When destruction of the eggs and young proceeds at this rapid rate, only species that produce vast numbers of eggs are likely to survive.

An unusual insect life history. You already know some things about insect reproduction. You know that the sexes are separate, and that most female insects are egg producers. You also know that some insect eggs hatch to produce larvae, and that other insect eggs produce nymphs.

In general, insects are like many other invertebrates in that their potential rate of reproduction is very rapid. But a high death rate keeps them from overpopulating the earth. Among insects are some unusual types of reproduction, such as that of the aphids.



20–6. Aphids in their natural habitat. (*Walter Dawn*)

These aphids or "plant lice" are small insects, often no bigger than a large pinhead. They live on all sorts of plants, both out-of-doors and in the home. They have sucking mouth parts which they use to puncture stems and leaves; then they feed on the plant sap. Aphids are among our most numerous and annoying insect pests. Aphids are shown in their natural habitat in Fig. 20–6.

In the fall of the year, female aphids lay eggs that survive the winter cold. In spring, these eggs hatch, and produce a generation of aphids composed entirely of females. Several more generations of females may be produced in the course of the summer. In some species, these summer generations are hatched from eggs that have not been fertilized. In other species the summer females bear their young. Then a last summer generation is produced, but half of this last generation is male and the other half female. Now the eggs are fertilized and deposited. They are not due to hatch until the following spring.

CRAYFISH EGGS

Crayfish are common in the fresh-water streams of North America. You often find them concealed under the edges of rocks along the shore. They are crustaceans, and therefore related to such animals as lobsters, crabs, and shrimp.

A FEMALE CRAYFISH AND HER EGGS In the spring you can often find female crayfish that are carrying masses of eggs on the undersides of their bodies. If possible, obtain such a specimen, and put it in a battery jar of water so that you can observe it.

Note how the eggs are attached to the body of the crayfish. Remove a single egg, and examine it under the low power of a microscope. If development has begun, you may find that the egg contains an embryo in some stage of growth. In its later development, the young crayfish forms a hard outer skeleton, which is shed every now and then as growth continues. The young crayfish remains attached to the female parent until growth and development are well advanced.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How are the crayfish eggs (or the young) attached to the body of the adult female?
2. How do you think the presence of a hard outer skeleton is related to growth and development?

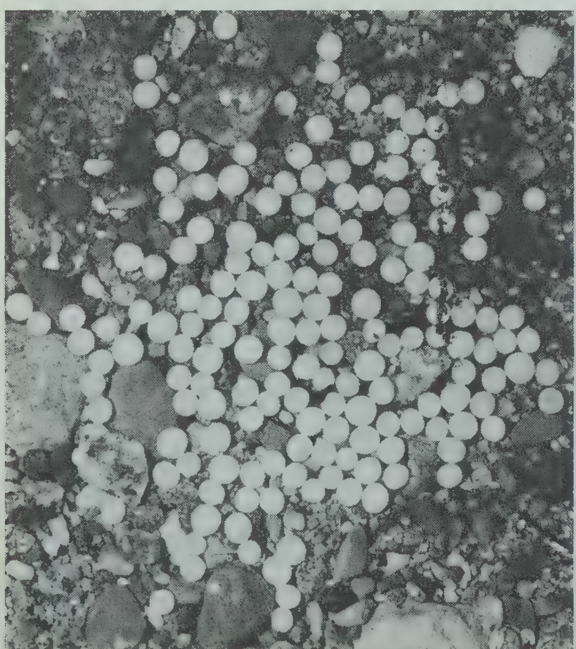
20–7. Female crayfish carrying a mass of eggs on the underside of her body. (*Robert C. Hermes from National Audubon Society*)

REPRODUCTION AMONG VERTEBRATES

Vertebrates are a good deal more complex than most of the invertebrates. Obviously, vertebrates cannot reproduce by simple cell division, because their bodies are made up of many cells. Nor do vertebrates form buds as do some of the simpler animals. Also, vertebrates have only limited ability to regenerate. Among these higher forms of life reproduction is sexual, and the sexes are separate in most cases. Some vertebrate females lay eggs, and others bear their young.

The reproduction of fish. Most fish are egg-layers, and the eggs are usually fertilized after they have left the body of the female. But there are exceptions to this rule. Female guppies, for example, give birth to their young.

The reproduction of the common yellow perch is more or less typical of this group. In the spring the ovaries of a female perch produce about 100,000 eggs. The female fish swims to a shallow spot along the shore and deposits these eggs. Then a male yellow perch discharges sperms from its testes into the water near the egg mass. No doubt some of the eggs fail to be fertilized. Many of the eggs that are fertilized are devoured before developing. Many of the young that do develop are destroyed by various animals that live in the lakes and streams.



20–8. The female trout lays her eggs on a sandy place at the bottom of a brook. (*Lynwood Chace from National Audubon Society*)

Some types of fish establish "nests" of eggs, generally in some gravelly spot in shallow water. They "guard" these nests until the eggs have hatched. One type of male catfish, that lives in the sea, carries the eggs produced by its mate in its mouth cavity, apparently as a means of protecting them.

Reproduction of amphibians. Frogs are examples of amphibians that spend the first parts of their lives in the water, and then develop into adults that can breathe air and live on land. Other amphibians, such as the common toad, have much the same kind of life cycle. But there are some species of amphibians that live entirely on land, and other species that never leave the water. Most female amphibians lay eggs, but a few types bear their young.

A female frog has two ovaries attached to the upper side of the body cavity. A male frog has two testes lying in about the same position. Eggs produced by the female frog break out into the body cavity, and then enter the oviducts. The eggs now pass through the oviducts to the exterior. They are fertilized by the sperm cells of a male frog, while the female frog is laying them. Eggs are deposited in masses in the shallow water along some shore. Each egg has a covering of jellylike material.

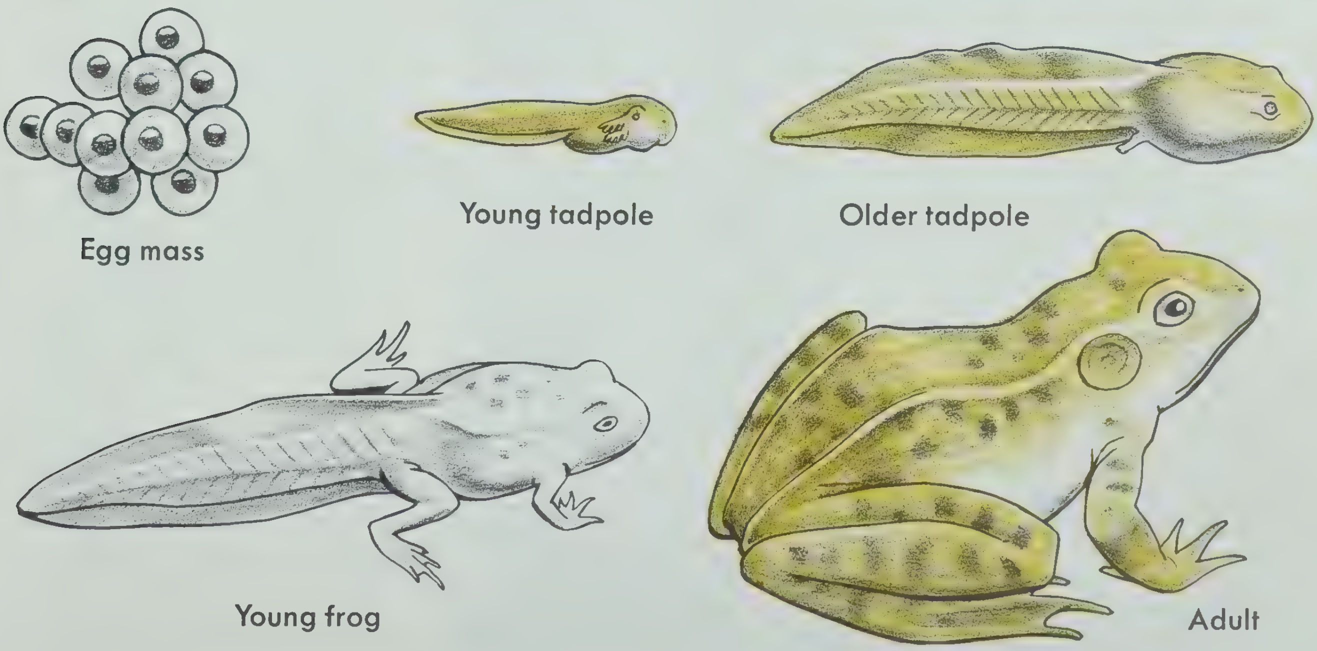
20–9. A newly-laid mass of frog eggs. What do you think is the relation between numbers of eggs produced and numbers of eggs that will actually grow into adults? (*Lynwood Chace from National Audubon Society*)

Early stages in the development of a frog take place within the egg. A tadpole is formed, and it breaks out of the egg to lead a free-swimming life. At first, the tadpole has gills on the outside of its body, as shown in Fig. 20–10. In older tadpoles, gills have developed inside the body, and the external gills have disappeared.

After the tadpole has become somewhat older and larger, lungs begin to form within its body. Meanwhile, hind limbs develop, followed by front limbs. The tadpole tail begins to be absorbed back into the body. Then comes the day when the the young frog crawls up on some sloping beach and begins to breathe air for the first time. But it can still get some oxygen through its moist skin layer. In fact, it spends the winter hibernating in the mud and water at the bottom of a pond. During this period, of course, the frog does not need as much oxygen as it does when it leads an active life.

Reproduction by reptiles. The reptiles include such animals as turtles, alligators, lizards, and snakes. Sexes are separate in the reptiles, as is the case with most vertebrates.

The great majority of female reptiles are egg layers. Female turtles, for instance, often lay their eggs in holes made on sandy shores of beaches,



20–10. The life cycle of a frog.

20–11. Young snapping turtle hatching from its egg. (*Lynwood Chace from National Audubon Society*)

ponds, and streams. Certain female lizards, however, bear their young. Among them are the "horned toads" of the Southwest, which despite their name, are short-tailed lizards. Garter

20–12. Cowbirds are known to lay their eggs in the nests of other birds. This cowbird is removing an egg from the nest of a warbler to make room for her own egg. (*Hal H. Harrison from National Audubon Society*)

snakes, water snakes, and the water moccasin are other types of reptiles whose eggs hatch within the bodies of the female parents.

Reproduction by birds. The birds are all egg layers. Adult females usually have only one ovary. It produces mature egg cells that are what we call "egg yolks." An egg yolk has a nucleus, which is tiny, and the rest of the yolk is largely stored food.

Such an egg cell is either fertilized before it leaves the ovary, or soon after it enters an oviduct. The egg is produced whether it is fertilized or not. On the way down the oviduct, the "white of the egg" is formed around the yolk. Then two shell membranes form around the egg white, and finally a shell is produced in the lower part of the oviduct.

Some female birds lay only one egg at a time, but others produce as many as twenty. Certain bird species make no nests at all, while others build elaborate nest structures. Some bird eggs hatch in 11 days, and others take much longer. An ostrich egg, for example, requires about 45 days to hatch, and eggs of one kind of albatross require 81 days.

Various newly hatched birds are quite helpless. Young robins, for instance, must be cared for by their parents for several days. Only then do they learn to fly and to seek food for themselves. Young chickens, on the other hand, are soon able to follow the mother hen, and to do their own feeding.

The female European cuckoo lays her eggs in the nests of other birds, and simply abandons them to foster parents. Our own North American cowbird does the same sort of thing. When a female cowbird is ready to lay an egg, she deposits it in a newly built nest of

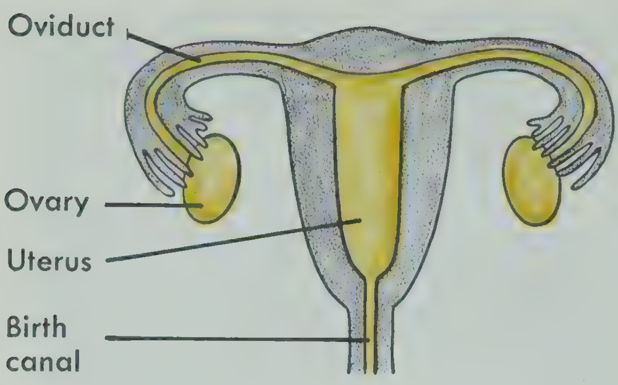
20–13. The duckbill, a native of Australia, lays eggs and suckles its young. (*Australian News and Information Bureau*)

some other bird species. A cowbird's egg hatches in about 11 days. The foster parents are soon busy feeding a young cowbird, which has an excellent appetite. Meanwhile, the female cowbird is off in some pasture with other adult cowbirds, seeking food for herself.

Reproduction of mammals. Three species of mammals, that live in the Australian and New Guinea region, are egg layers. They are the duckbill, and two types of spiny ant eaters. Like all mammals, they have hair, and the spiny ant eaters also have bristles similar to the quills of a porcupine. Females of these three species produce milk, which oozes out on the hair of their abdomens, where it can be licked up.

The reproduction of kangaroos and opossums also differs from that of most mammals. Kangaroos are from the Aus-

20–14. Young opossums getting a free ride. (*Rue from Annan Photo Features*)



20–15. Reproductive structures of a female mammal.

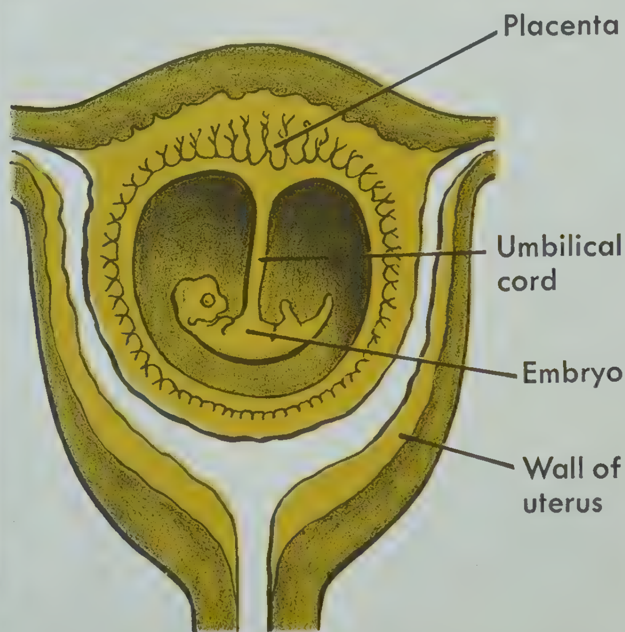
tralian area, but opossums are native to North and South America. Females of both types produce eggs, which have no shells, and remain in the body of the mother until they have developed Then the young are born in a very immature state. These young are small and quite helpless, and they are carried around in a pouch on the lower side of the female's body. When they grow larger, the young of the opossum often ride around on the mother's back.

Other female mammals reproduce in a different way. Fig. 20–15 shows the reproductive structures of such a mammal. There are two ovaries and two oviducts that connect with a ***uterus*** (*you*-ter-us). From the uterus a birth canal leads to the outside.

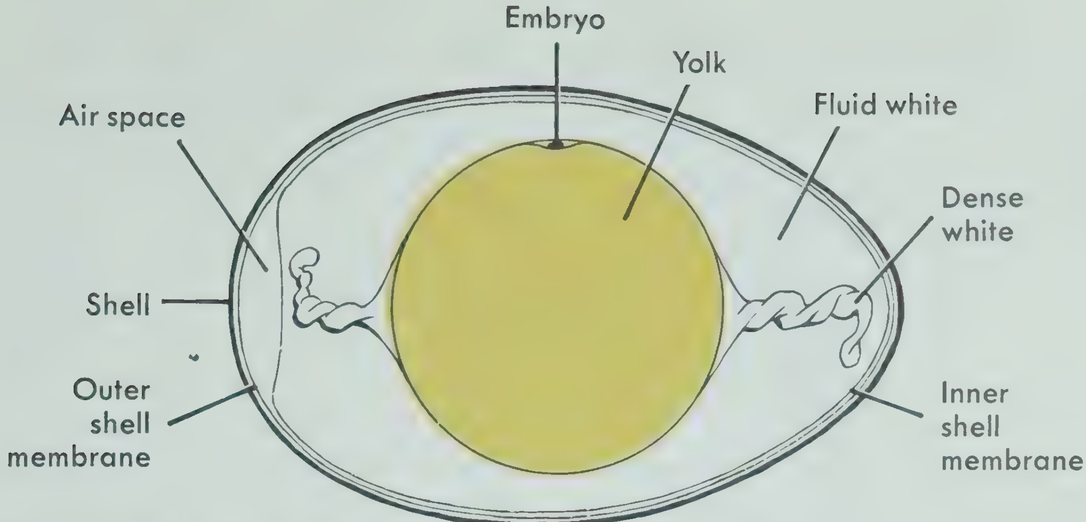
Sperms from the male make their way up through the uterus and into the oviducts. An egg cell, that is on its way down an oviduct, unites with a sperm cell to form a fertilized egg cell. This fertilized egg cell becomes attached to the inner wall of the uterus. Later, a special structure is developed; it is called the ***placenta*** (pluh-*sen*-tuh), and is shown in Fig. 20–17.

In some mammals, the placenta is formed in part from cells that line the uterus. The rest of it comes from cells produced by the developing offspring. An ***umbilical*** (um-*billik*-ul) ***cord*** connects the placenta with the young mammal. Through this umbilical cord, blood vessels bring food to the young, and other blood vessels carry away waste products. In the wall of the placenta, blood vessels from the young and from the adult come close to each

20–16. A four-day-old human embryo. (*Courtesy, L. B. Shettles, Ovum Humanum, Hafner Publishing Co., N.Y.*)



20–17. A diagram of the mammalian uterus and placenta.



20–18. A diagram of an egg.

other, but do not actually connect. Foods and wastes must pass through cell membranes in going from one blood system to the other.

When the time of birth arrives, the walls of the uterus contract, and the young mammal is forced out through the birth canal. The umbilical cord is either cut or broken in this process. Now the young must begin to breathe, and to take food by way of its mouth.

Fig. 20–17 shows a case in which only one young is going to be produced. But as you know, various mammals produce more than one young at a time. In such cases, each young mammal must have its own connection with the placenta. Actually, the placentas formed by different species of mammals vary a good deal.

STRUCTURE OF AN EGG

Tap one side of a fertile hen's egg with the handle of a scalpel, until you have produced a number of small cracks in the shell, covering an area about the size of a quarter. Be careful not to push the cracked part of the shell down into the egg. Now put the egg in some container that will hold it in a fixed position, with the cracked side upward.

Using a fine-pointed forceps, carefully pick away the cracked pieces of shell. Beneath the shell will find an outer shell membrane and an inner shell membrane. Cut through these membranes along one side of the opening, and lift them away. Now you can see the yellow egg yolk. On top of the egg yolk is a spot which marks the place where the chick embryo develops.

Remove more of the shell and the shell membranes until you can see some of the egg white. On either side of the yolk you will find twisted coils of dense egg white; they serve to turn the yolk so that the embryo is always on the top side. The rest of the egg white consists of a moderately dense portion next to the yolk, and a more fluid portion out near the shell. A diagram of an egg is shown in Fig. 20–18.

ANALYSIS Prepare answers to the following questions in your notebook:

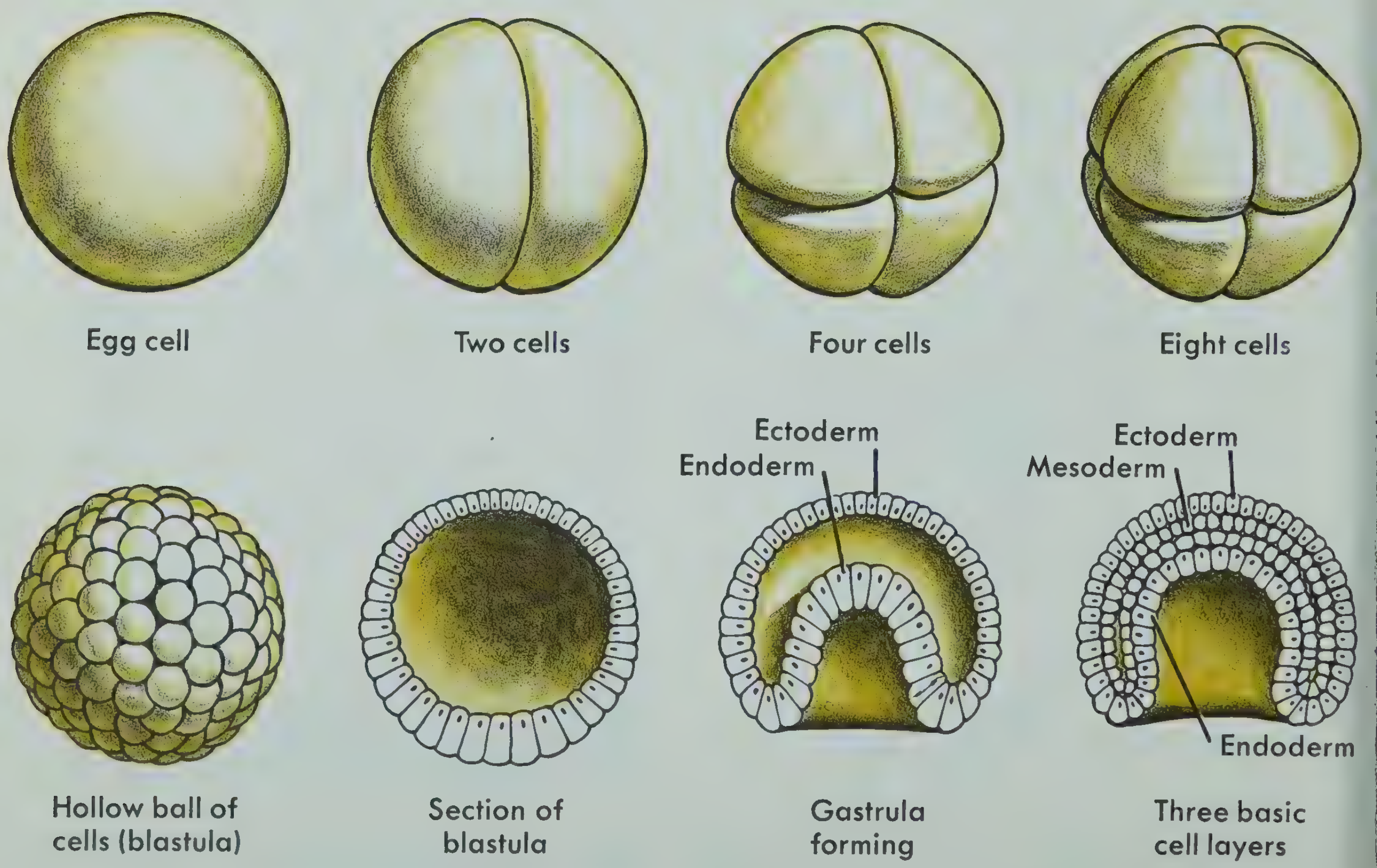
1. What purpose do you think is served by the egg yolk? The egg white?
2. Do you see any advantage in having the embryo on the side of the yolk that is upward? Explain.

ANIMAL DEVELOPMENT

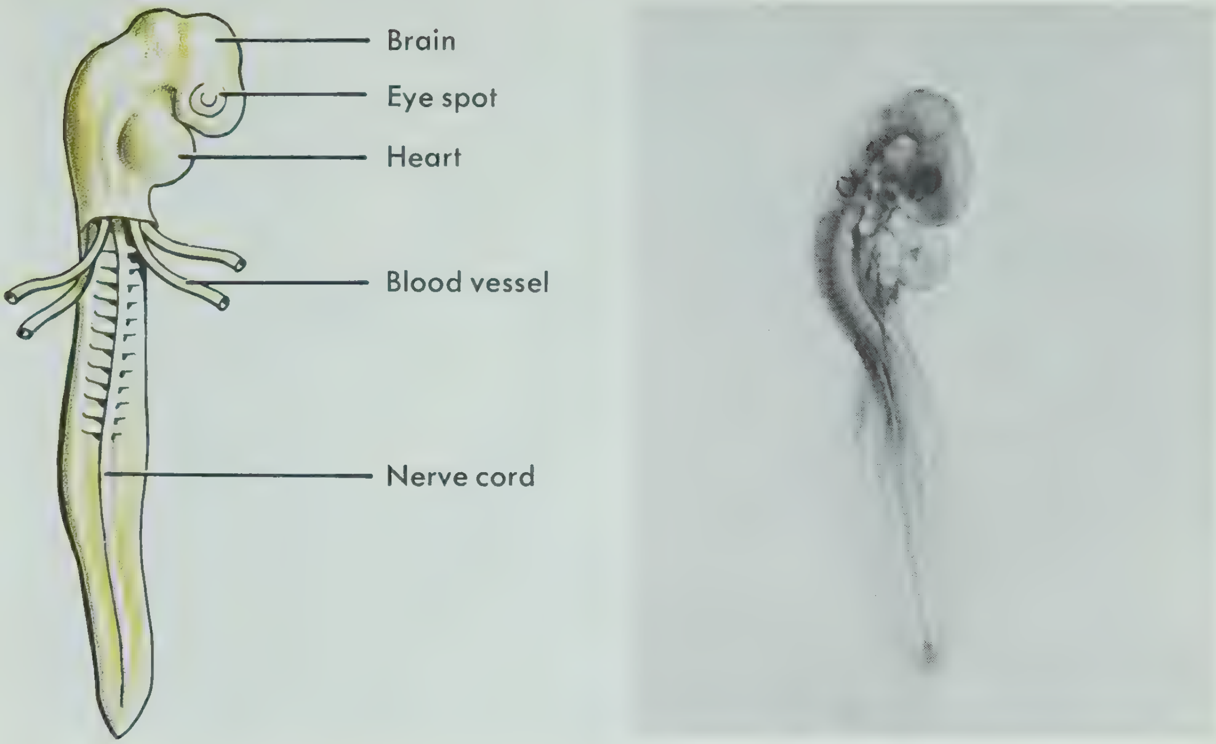
The process of development in animals varies, but in some ways it is more or less the same. For instance, it begins with a single cell—the fertilized egg. This cell contains the genes and the *DNA* that will produce a given type of animal. One combination of genes and their *DNA* results in the development of a cat. Another combination of genes and their *DNA* leads to the production of a dog. But in either case, the story begins with a single cell.

Another similarity is that cells must divide rapidly to produce the many cells that form the adult body. At the same time, special types of cells must be developed. Some cells must become nerve cells, gland cells, muscle cells and all of the other types of cells that go to form the animal body. The fact that a fertilized egg cell contains the *DNA* molecules necessary to direct all of this development may seem surprising.

Early stages in development. Early stages in the development of a starfish are shown in Fig. 20–19. At first, the egg and its daughter cells simply divide. A hollow ball of cells is formed, and is called a ***blastula*** (*blas*-tue-*luh*). You can see in this diagram that a blas-



20–19. Early development of a starfish.



20–20. Left, a diagram of a chick embryo after two days of development. Right, a photograph of a chick embryo at the same stage in development. Identify the structures in the photograph (right) that are labeled in the drawing (left). (*Ward's Natural Science Establishment, Inc., Rochester, N.Y.*)

tula is made up of many cells, and that it has a hollow center.

The three basic cell layers. After a starfish blastula has developed, other changes take place. First, one side of the blastula begins to push inward, as shown in Fig. 20–19. As a result, the organism assumes a cuplike form. One layer of cells forms the outside of the cup, and another layer of cells lines the cup. At this stage, it is called a ***gastrula*** (*gahs*-truh-*luh*). The outer layer of cells is called the ***ectoderm*** (*ekto*-derm), and the inner layer of cells is called the ***endoderm*** (*endo*-derm).

Soon a third layer of cells, the ***mesoderm*** (*messo*-derm), develops between the first two cell layers. So now there are three basic cell layers: the ectoderm, the mesoderm, and the endoderm. As development goes on, various tissues are formed from the cells of these basic layers. In various animals, these tissues are as follows:

From the ectoderm
- outer skin layer
- hair, nails, feathers, scales, and plates
- the nervous system

From the mesoderm
- the sex cells
- muscle and connective tissue
- the internal skeleton

From the endoderm
- linings of the digestive system and various internal organs

In the preceding discussion we have been talking about the starfish. But the same three basic layers are developed in all embryos above the level of a hydra. Also, the same adult tissues are derived from them. Your own nervous system, for example, was developed

20–21. A newly-hatched chick. (*Grant Heilman*)

from the ectoderm layer of the embryo from which you grew.

Variations in development. Some cases of animal development are more complex than that of a starfish. In the case of a hen's egg, for instance, only the egg nucleus divides. It does this a number of times, and a group of cells forms on the surface of the egg yolk. This group of cells develops ectoderm, mesoderm, and endoderm layers, and an embryo is formed.

Fig. 20–20 shows such an embryo after two days of development. The three germ layers have already given rise to tissues, organs, and systems. The embryo continues to lie on the surface of the yolk. From the egg yolk, it obtains the food needed for further growth and development. After a time, all of the yolk has been used, and now the egg white provides an additional food supply. On the twenty-first day, the chick breaks through the shell.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column. Write in the statement from the second column that goes best with each of the words.

1. blastula	A small insect that feeds on plant sap.
2. placenta	Connects the placenta with the developing mammal.
3. aphid	A hollow ball of cells formed during development.

4. uterus	Structure for the nourishment of developing mammals.
5. umbilical cord	Structure of female mammals in which the young develop.
6. gastrula	The third basic cell layer of an embryo.
7. mesoderm	Young animal that has two of the basic cell layers.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Certain types of animals are able to reproduce asexually.
2. An ameba has a permanent body form, and is therefore unable to change shape.
3. Malaria parasites form a type of spore while they are in the stomachs of mosquitoes.
4. Somatic cells are any cells that produce mature sperms and mature egg cells.
5. Special sex cells are formed in the reproduction of a volvox colony.
6. Sponge and coral colonies are able to move about on the bottom of the shallow sea.
7. Sponges and corals develop special sex cells and free-swimming embryos.
8. Among flatworms, the testes and ovaries are formed in different individuals.
9. About half of the flatworm and roundworm eggs that are produced develop into new adults.
10. Some species of planaria reproduce by forming male and female sex cells.
11. Earthworms are unable to regenerate parts.
12. The eggs of a female oyster are fertilized before they are discharged into the water.
13. As soon as they are mature, a female crayfish discharges her eggs into the surrounding water.
14. A number of the vertebrates that live in the water reproduce by budding.
15. Among the fish, individuals usually are either males or females.
16. Some species of fish do not lay eggs, but bear their young.
17. A female frog's eggs are fertilized before they leave her body cavity.
18. A very young frog tadpole has gills on the outside of its body.

19. Some species of reptiles are egg layers, but other reptiles bear their young.
20. Young birds are usually able to find their own food about 24 hours after they have hatched.
21. The female duckbill is unusual, because she does not produce milk.
22. The young of kangaroos and opossums are quite immature at the time of birth.
23. The placenta is a structure which serves to nourish a developing, but unborn, mammal.
24. A fertilized egg cell contains *DNA* molecules which determine what kind of organism it will produce.
25. The fertilized egg cell of a cat contains the same *DNA* molecules that are in the fertilized egg cell of a dog.
26. A starfish blastula is a hollow ball of cells.
27. A starfish gastrula contains two of the three basic cell layers.
28. The nervous system and the outer layer of the skin develop from the mesoderm layer of an embryo.
29. The linings of certain internal organs develop from the endoderm layer of the embryo.
30. When a hen's egg begins to develop, the entire egg cell divides several times.

DISCUSSION QUESTIONS

1. What kinds of reproduction are represented among the simpler animals?
2. By what sort of process does an ameba divide?
3. How are cysts related to spore formation in the case of protozoa?
4. What is the difference between somatic cells and sex cells?
5. How does the budding process relate to the growth of sponge and coral colonies?
6. Describe reproduction in the flatworms. How does reproduction in the roundworms differ from reproduction in the flatworms?
7. In what way does cross-fertilization take place in earthworms?
8. How does regeneration in a planarian compare with regeneration in an earthworm?
9. How can you account for the fact that so many oyster eggs fail to produce new oysters?
10. In what ways is the reproduction of an aphid unusual?
11. To what extent does a female crayfish provide care for her eggs and young?
12. How does a yellow perch reproduce? In what ways does this differ from the reproduction of some other fish?

13. In what ways does a frog obtain oxygen at various stages in its life cycle? How is it possible for an adult frog to remain underwater in the winter?
14. What are the various stages in the formation of a hen's egg? When is the egg fertilized?
15. What is unusual about the reproduction of duckbills and spiny ant eaters? Kangaroos and opossums?
16. How is the presence of a uterus related to the development of a young mammal?
17. What is the function of the placenta in mammals? How is it related to the uterus?
18. In what ways are the *DNA* molecules in a fertilized egg cell related to what the egg cell will produce?
19. What is a blastula? A gastrula? How are they related to each other?
20. What are the three basic cell layers, and what structures develop from them?
21. How does the early development of a starfish differ from the early development of a bird?

THINGS TO DO

1. Prepare a bulletin board display of sketches and pictures to illustrate the different ways in which various animals reproduce.
2. Plan an experiment to test regeneration in earthworms. You can keep a dozen worms in a two-quart battery jar full of loam soil. But you have to add some chopped up humus to the soil about every third day, since the worms depend upon it for food. Keep the soil moist, but never wet. If your teacher approves of your plan, carry out the experiment.
3. Mealworms are the larvae of beetles, and can be obtained from supply houses. They are often raised in laboratories as food for other animals. Simply put them in a gallon battery jar that contains a mass of torn-up paper and some bran or oatmeal. Cover the jar with a piece of screen or cheesecloth. If you start out with the mealworms (larvae), they will form pupae before long. Then the adult beetles emerge and begin to produce eggs. Soon you will have another generation of larvae. Examine your specimens about every third day.
4. Plan a class visit to a fish hatchery if one is nearby. Find out how the fish eggs are obtained, how they are hatched, and how the young fish are raised to insure their survival.
5. With the help of your teacher, plan and produce an incubator. You need a box about two feet square, with a door in one side. Install an electric light socket on one interior wall of the box. An electric

bulb will provide the necessary heat. Test various bulbs until you find the size that will keep the temperature inside the box at about 103°F. See if you can incubate some fertile hen eggs.

6. Examine prepared slides of whole chick embryos. Compare 24-hour, 30-hour, and 48-hour stages of development. Prepare a report on how a chick embryo grows and develops.

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CHAPTER 21

Inheritance in Plants and Animals

Since men have raised plants and animals for thousands of years, you may be sure that man's interest in heredity goes back to ancient times. It is obvious that heredity is a powerful force in determining what sorts of cattle, vegetables, or grain are produced. Until fairly recent times, however, no one really knew very much about this subject.

A century ago, farmers did just what their ancestors had done before them. They collected the seeds from their best plants, and used the seeds to produce the next crop. They reserved their best stock animals to produce new animals. This age-old process is called ***mass selection.*** Over a long period of time they got improvement in the plants and animals they raised. But in many cases the improvement came slowly.

The modern study of heredity began with the Austrian monk, Gregor Mendel. During the latter part of the past century, Mendel was busily crossing short peas and tall peas in his garden. If you use the pollen from a short plant to fertilize the flower of a tall plant, you get such a *cross.* Mendel kept records of each seed and what it produced.

Mendel published his findings in 1866, but at that time very little attention was paid to them. In 1900, when there was growing interest in the study of heredity, Mendel's long-forgotten results were re-examined. Other scientists began to test them in similar experiments. They soon found that Mendel had discovered the basic laws of heredity.

THE CAUSES OF VARIATION

In your earlier studies, you learned that no two members of any species are exactly alike. Rather, they exhibit indi-

21–1. Notice the marked differences among the pigs in this litter. (*Grant Heilman*)

vidual differences. This ***variation*** (*vair*-ee-*ay*-shun) of one individual from another is the rule, rather than the exception in nature.

We probably tend to overlook many individual differences, because we "are not looking for them." A dozen chickens may seem more or less alike, until we examine them with care. Then we begin to notice differences in size and color pattern. Some of these differences have been inherited. We may also note that one bird has lost a small piece of its comb, and another has a toe missing. Many of the differences are minor, but they add up to the fact that each bird has its own combination of characters.

We are more accustomed to noticing differences among people, because we depend upon these differences to recognize our friends. One person is tall and has brown hair; another is short and has red hair. But even so, we usually overlook a good many small differences, such as the presence or absence of scars or moles, the length of fingers, and similar items. We are also limited to observing what is on the outside of the body. Variations in the structure of internal organs also exist.

The causes of variation. Now it is appropriate to ask why the members of a species differ from one another. We shall find our answer by studying two general forces that affect the individual; one of these forces is *heredity*, and the other is *environment*.

You have seen that the complex plant or animal begins life as a single cell: the fertilized egg cell. In this cell are pairs of chromosomes. Genes are located in these chromosomes. It is these genes that determine what the heredity will be.

Whether you are a male or female, for instance, depends upon what happens to be inherited. One pair of chromosomes is involved. These *sex chromosomes* are of two types: an *X* type, and

a Y type. A female has two X chromosomes (XX), and a male has one X chromosome and one Y chromosome (XY). So all mature egg cells carry one X chromosome. Half of the mature sperm cells carry X chromosomes, and the other half carry Y chromosomes. The sex of an offspring is determined at the moment a mature sperm cell unites with a mature egg cell. If the sperm carries the X chromosome, the resulting combination is XX—a female. If the sperm carries the Y chromosome, the resulting combination is XY—a male. The same kind of sex determination is known to operate in certain other animals and in some plants.

From the standpoint of heredity, an individual is really a combination of characters. Some of these characters are related to one another in the process of heredity, and others are quite unrelated. Thus, a nearsighted man may be born deaf, with club feet, blond hair, blue eyes, and a curved spine. Or, a nearsighted man may have normal ears and feet, brown hair, brown eyes, and a normal spine. In fact, there are many possible combinations of these factors, to say nothing of many other factors. What they inherit is one reason why individuals vary.

Another general cause of individual differences is the effect of *environment.* From the time the fertilized egg cell is formed until the end of the life cycle, the environment influences what the individual will be. In fact, if the environment is sufficiently unfavorable, the individual will not survive. But even in a fairly favorable environment, some individuals have one set of experiences, and other individuals have another set of experiences. All individuals are variously affected and changed by these experiences.

So individuals begin their existence with differences due to heredity. Other differences caused by things and forces of the environment are soon added. It is

21–2. Left, paired human male chromosomes; right, paired human female chromosomes. (*Tjio and Puck, P.N.A.S. 44, 1958*)

no wonder that *variation* is one of the most obvious facts of life.

Hereditary characters and acquired characters. Hereditary characters are passed on to offspring by their ancestors. But some of them can be greatly modified by contact with the environment.

Let us consider the case of a rat's tail, as an example. A long tail is something that a rat inherits. But suppose a young rat has a fight in which it loses its tail. The rat survives, but is tailless the rest of its life. This bobtailed condition is an *acquired character*. Some of the rat's somatic or body cells have been affected; in fact, they have been lost. But the rat's sex cells were not involved, and are unchanged.

Now suppose the rat has offspring. Would you expect them to be bobtailed? Remember: nothing has happened to the rat's sex cells. The answer is that the rat's offspring will have normal tails. The acquired character is *not* inherited, because it is not represented by a change in the sex cells.

Or suppose you plant an acorn on some exposed ridge that is windswept and has a rocky soil. An oak tree sprouts and grows, but it is stunted and misshapen due to the unfavorable environment. The tree does produce some acorns. Now you plant these acorns where conditions are favorable. Do they produce stunted and misshapen oaks? No indeed, the new oak trees are quite normal.

Mutations are hereditary changes. If forces of the environment do not produce hereditary changes in the form of acquired characters, how do such changes come about? The answer is that the *DNA* molecules in the genes of sex cells are sometimes altered, and when this happens a ***mutation*** (mew-*tay*-shun) occurs. Since it is due to a change in the genes of sex cells, a mutation can be inherited. Heat, cold, certain chemicals, and X rays have been known to produce mutations in laboratory organisms. Mutations also occur in nature, presumably due to similar causes.

21–3. This common mold, *Neurospora*, is widely used in research concerning mutations. (*David R. Stadler*)

Probably a great many mutations are of such a minor nature that they tend to be overlooked. Another group of mutations are so damaging that they cause early death of the individuals concerned. Mutations of this damaging type may also fail to be observed, because they do not appear in adult populations.

Some naturally occurring mutations have produced major changes that we have found useful. Back in 1791, such a mutation produced a lamb with a long back and short, bent legs. The Massachusetts farmer who owned the lamb saw that it would not be able to jump over stone fences. So the lamb was preserved, and it became the ancestor of

the Ancon breed of sheep. Ancon sheep remained popular in the stone-fence country of New England for many years.

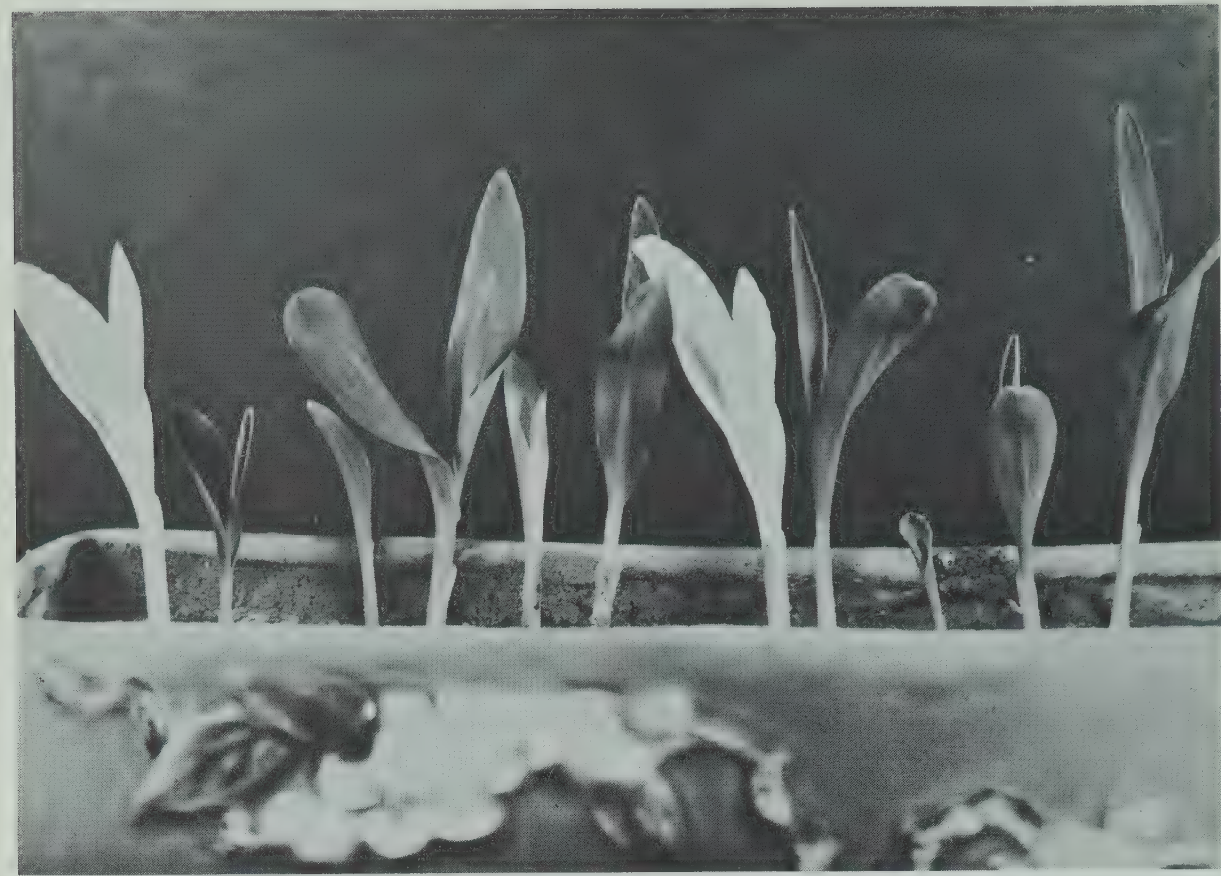
In 1889, all Hereford cattle had horns, which were a nuisance because the horned cattle often injured one another. But in that year, a hornless Hereford calf was born on a Kansas farm. It became the ancestor of polled (or hornless) Hereford cattle. But do not overlook this important point: hornless cattle were "good" from the human standpoint alone. Since they are protected by man, the lack of horns was no handicap to the cattle. But suppose they had been wild cattle sought by wolves and other natural enemies. In this case, the hornless type might not have survived.

Many other mutations have appeared among the plants and animals that we raise. Some of them have led to the development of new varieties. Navel oranges, nectarines, extra large blueberries, and the delicious apple, as well as various types of flowers are products of mutations. So are several kinds of foxes and mink that we raise for fur. You can readily see why plant and animal breeders are on the lookout for such hereditary changes. Some of them can be used to advantage.

Harmful and desirable mutations. Mutations that cause the early death of an individual are certainly harmful, so far as the individual is concerned. But since the individual does not survive, such mutations do not become part of the heredity of the species. They are not passed on to other individuals.

If the mutations do not cause early death, however, the story may be some-

21–4. Ancon sheep, shown above, resulted from a mutation producing short legs. (*LIFE Magazine*)



21–5. What is a mutation? Does this photograph illustrate a harmful mutation? Explain. (*A. M. Winchester, Biol. Dept., Colo. State Coll., Greeley, Colorado*)

what different. You now have the question of whether the mutations aid or handicap the species. A mutation that causes a physical defect, such as blindness, is clearly a handicap. On the other hand, a mutation that renders a germ immune to some drug we commonly use would clearly be an advantage to the germ species, although it would be unwelcome as far as we are concerned.

In a state of nature, the majority of mutations are harmful. At the same time, many of them are so minor that they have little consequence. And there is always the possibility that some very beneficial mutations will occur. We should not forget that mutations probably have been taking place for centuries. Without them, modern types of plants and animals would not exist.

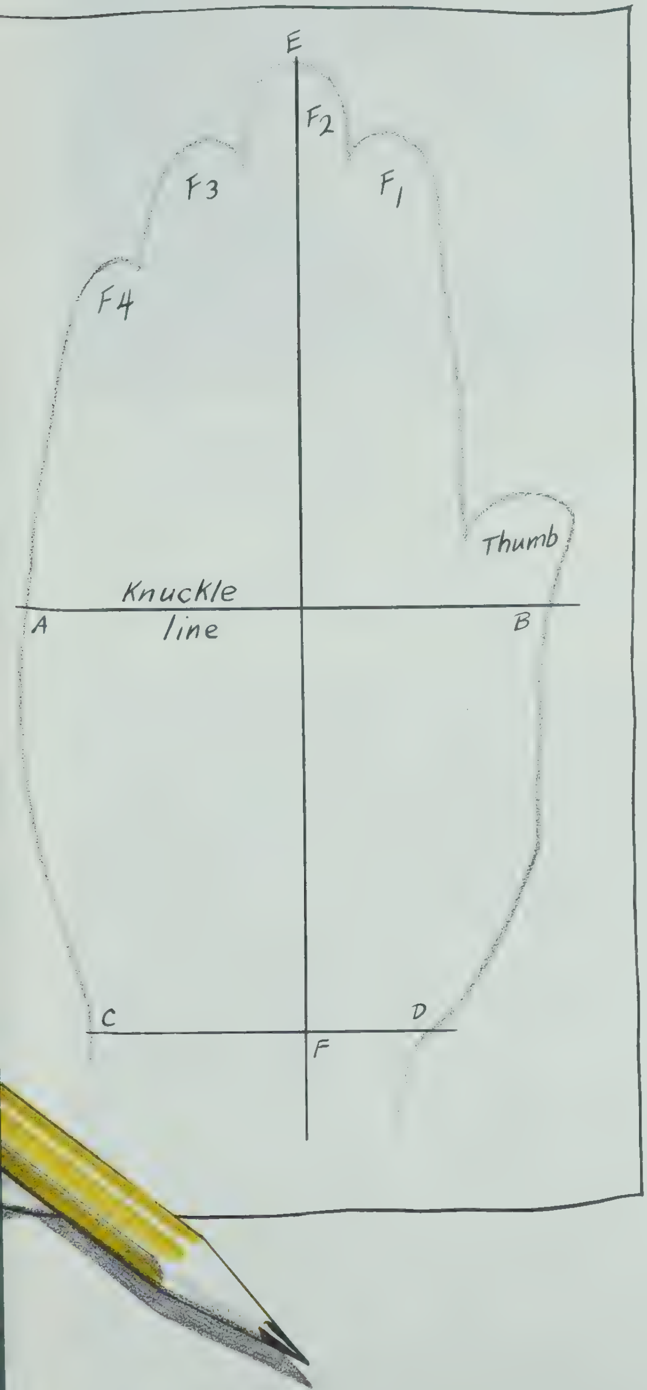
SOME OBSERVATIONS OF VARIATIONS

The adult human body is a combination of many characters, all of which can and do vary. For example, the size and shape of hands vary a great deal.

YOUR OWN HAND Put your left hand down flat with the fingers together on a piece of paper. Holding a pencil vertically, trace around the hand so that you have an outline like Fig. 21–6. Draw line *AB* at the level of your knuckles, and line *CD* where your wrist begins. Draw line *EF* from the tip of your longest finger down to the wrist line.

Label the thumb and fingers as shown in Fig. 21–6.

Note first, whether *Finger 1* is shorter, longer, or the same length as *Finger 3*. Now measure the distance from *E* to *F*, and divide the result by the distance from *A* to *B*. Compare your results with those of other students. To what extent do the results agree and disagree?



21–6. The size and shape of human hands vary greatly from person to person.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did all students have *Finger 1* longer than *Finger 3*? Or, did this result vary from person to person?
2. Did all students get the same result when they divided line *AB* into line *EF*? Are some hands broader than others? Longer than others?

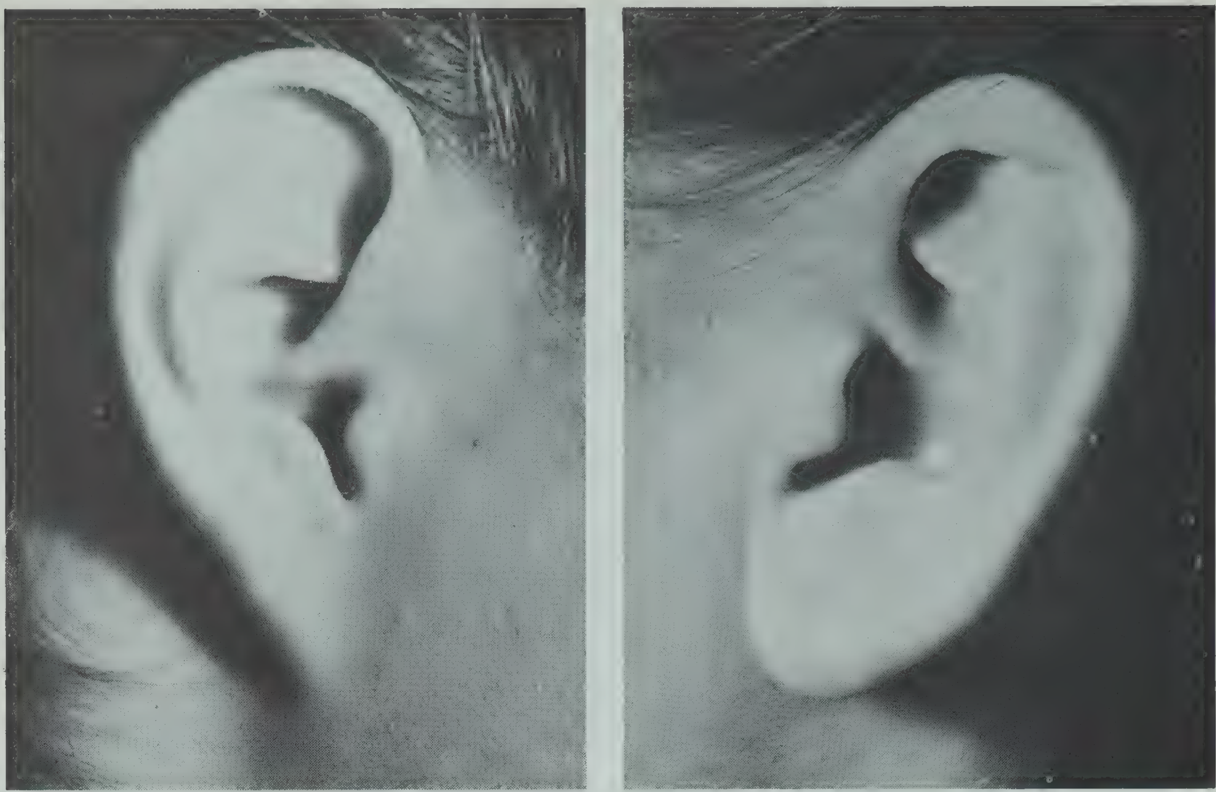
YOUR EAR LOBES The lower end of your ear may have a lobe that hangs down about a third of an inch from the point at which the ear is attached to your head. Call this a "free lobe." But some people have the lower end of the ear attached to the side of the head. Call this an "attached ear." The type of ear you happen to have is determined by heredity.

Find out whether your ears have "free" or "attached" lobes. Compare your result with those of other students. (See Fig. 21–7.)

ANALYSIS Prepare answers to the following questions in your notebook:

1. How many students had "free" ear lobes? "Attached" ears?
2. Were there any cases in which it was difficult to say whether the ears had "free lobes" or were "attached"? Any cases in which the right ear differed from the left? Explain.

VARIATION IN LEAVES Let us now examine some variations that may be largely due to the effect of environment. Find a tree, on the edge of a woodlot, that has one side well shaded by other trees, and the other side in open sunlight. It must be a tree from



21–7. Left, "attached" ear lobe; right, "free" ear lobe. Do you have "attached" or "free" ear lobes? (*A. M. Winchester, Biol. Dept., Colo. State Coll., Greeley, Colo.*)

which you are free to pick a few leaves. Select leaves that are fully formed and at about the same height above the ground.

Pick 20 leaves from each side of the tree. Keep the sunny side and the shady side leaves carefully separated. Spread them out on a table top. Note any differences in color or form that may appear. Measure the length of each leaf, and record the data as follows:

Shady side leaves (length mm.)	*Sunny side leaves (length mm.)*
No. 1	No. 1
No. 2	No. 2
No. 3, etc.	No. 3, etc.

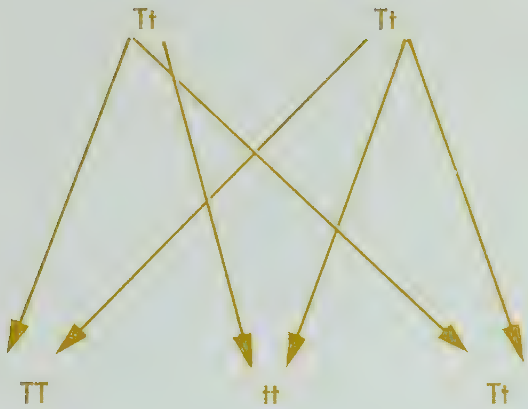
Prepare a graph of your data, using length in millimeters as units on the horizontal axis, and numbers of leaves of each length as units on the vertical axis. Use different colors to represent the graph lines of shady side and sunny side leaves.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Did the shady side leaves tend to be longer or shorter than the sunny side leaves?
2. Did you observe any other variations in the leaves? Explain.
3. What variations do you think were caused by the effects of environment?

MENDEL'S LAWS

Now let us return to Gregor Mendel and his basic laws of heredity. Let us assume that a pea plant has a pair of genes that determines how tall it will



21–8. Are these all the possible combinations from two hybrid parents?

be. Gene *T* carries the heredity for a tall plant, and gene *t* carries the heredity for a short plant.

Gene combinations. Each adult pea plant has two of these genes in each of its cells. One gene came originally from a sperm nucleus, and the other from an egg cell nucleus. When the sperm fertilized the egg cell, these two genes were brought together. So they now appear in all of the cells of the adult pea plant. What combinations of the genes *T* and *t* could exist in such a plant? If you think about this for a moment or two, you will see that there are just three possibilities. The gene combinations must be either *TT*, or *Tt*, or *tt*.

The nature of hybrids. A pea plant that gets a *T* gene from one parent and a *t* gene from the other parent is called a ***hybrid*** (*hy*-brid). That is, this pea plant is a hybrid so far as height is concerned, because it carries two opposed hereditary tendencies. But note that it may not be a hybrid, so far as other characteristics are concerned.

The *TT* combination, on the other hand, is one in which the genes carry the same tendency: the tendency to produce tall plants. Similarly, in the *tt* combination both genes of the pair carry the tendency to produce a short plant.

One of Mendel's experiments. Mendel carried out an experiment in which he crossed pure tall (*TT*) peas with

21–9. Most of the corn we raise today is hybrid corn. (*DeKalb Agricultural Assoc.*)

pure short (tt) peas. Clearly, each tall parent passed on one T gene to the offspring, and each short parent passed on one t gene. So for the character of tallness, all of the offspring were Tt, which is another way of saying that they were hybrids.

A good way to see what happens is to use a square divided into four parts. Along the top of the square indicate the genes that come from one parent, and along the side of the square, the genes that come from the other parent. Suppose, like Mendel, you cross a tall (TT) pea and a short (tt) pea. Copy the following figure in your notebook.

		Genes from tall plant	
		T	T
Genes from short plant	t		
	t		

Now fill in the spaces. For each space take one gene from the top margin, and one gene from the side margin. In this example, you get four hybrid combinations, as follows:

	T	T
t	Tt	Tt
t	Tt	Tt

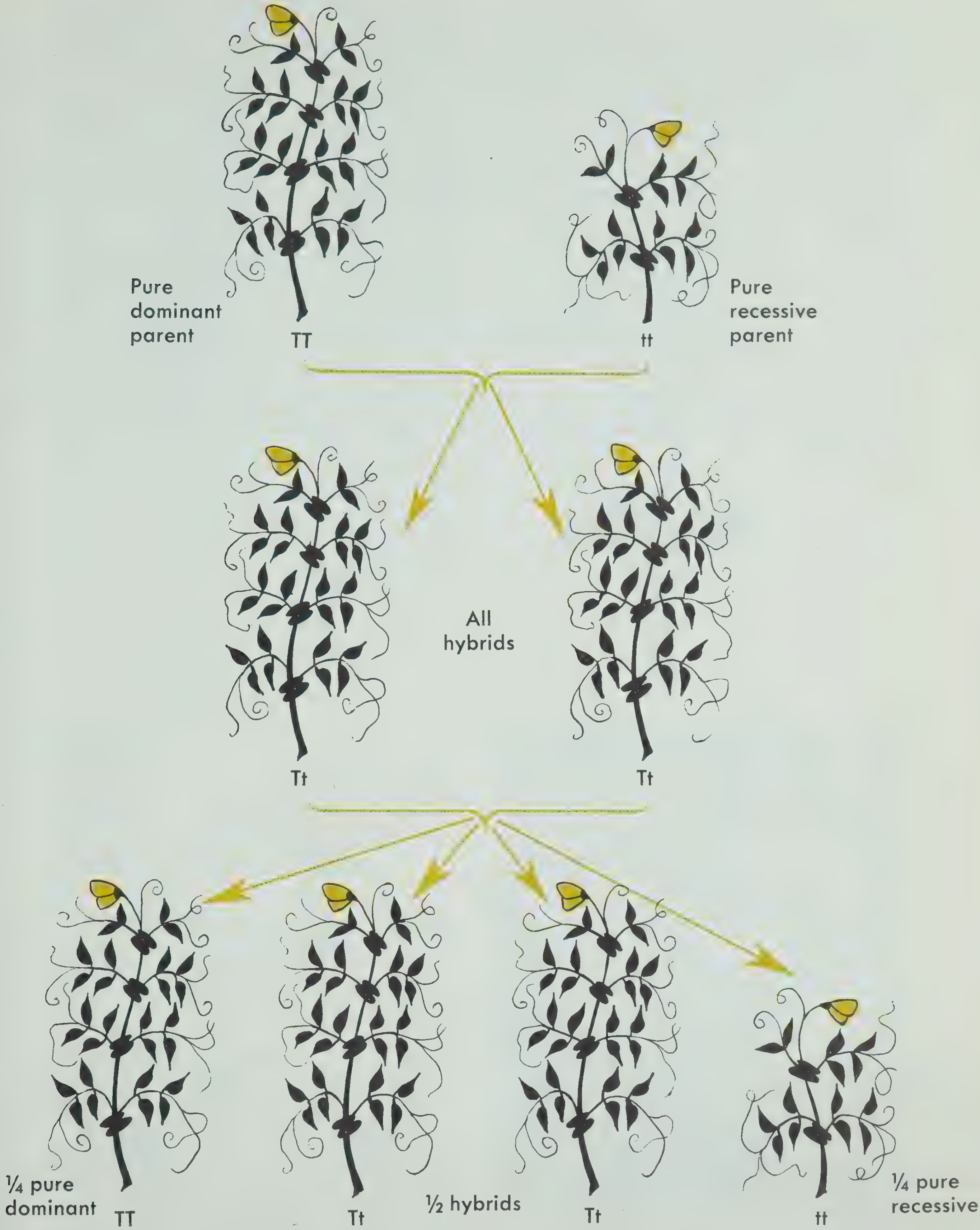
Dominant genes. How tall would you expect the hybrids to be? Probably most people would guess about half way between the tall parent and the short parent. Perhaps Mendel himself was surprised by his results. At any rate, the hybrid peas (Tt) were just as tall as their tall (TT) parents. We can now say, the T gene is *dominant* over the t gene. Whenever one T gene is present, the plant will be tall. We say that the t gene is *recessive,* because its tendency is suppressed when the T gene is present. The results illustrate Mendel's ***law of dominance. The law states that one factor in a pair may mask or prevent expression of the other.***

Crossing hybrids. Mendel now took hybrids (Tt) from the first generation of offspring and crossed one with another. We can see what happened by using the same squares we used before. Each parent in this cross provided both T and t genes.

		Genes from male parent	
		T	t
Genes from female parent	T	TT	Tt
	t	Tt	tt

Here again was a bit of a surprise. Out of every four offspring, three pea plants were tall, and one was short. You could predict that among the three tall plants, one was TT, and the other two were Tt. The short plant could only be tt. Actually, if you selected only four of these offspring at random, you might not have three tall plants and one short plant. But if you selected 100 plants at random, you would come close to having 25 TT, 50 Tt, and 25 tt. So you would have 75 tall plants and 25 short plants. (See Fig. 21–10.)

Incomplete dominance. Studies made after Mendel's time brought forth some other surprises. One was the discovery that in some gene pairs, neither gene was fully dominant. The plant known as the four-o'clock will serve as an example. When you cross a red four-o'clock plant (rr) with a white four-o'clock plant (ww), all of the first generation hybrid flowers are pink (rw). If r were dominant, the rw plants would have red flowers. But, the fact is, they bear pink flowers. In incomplete dom-



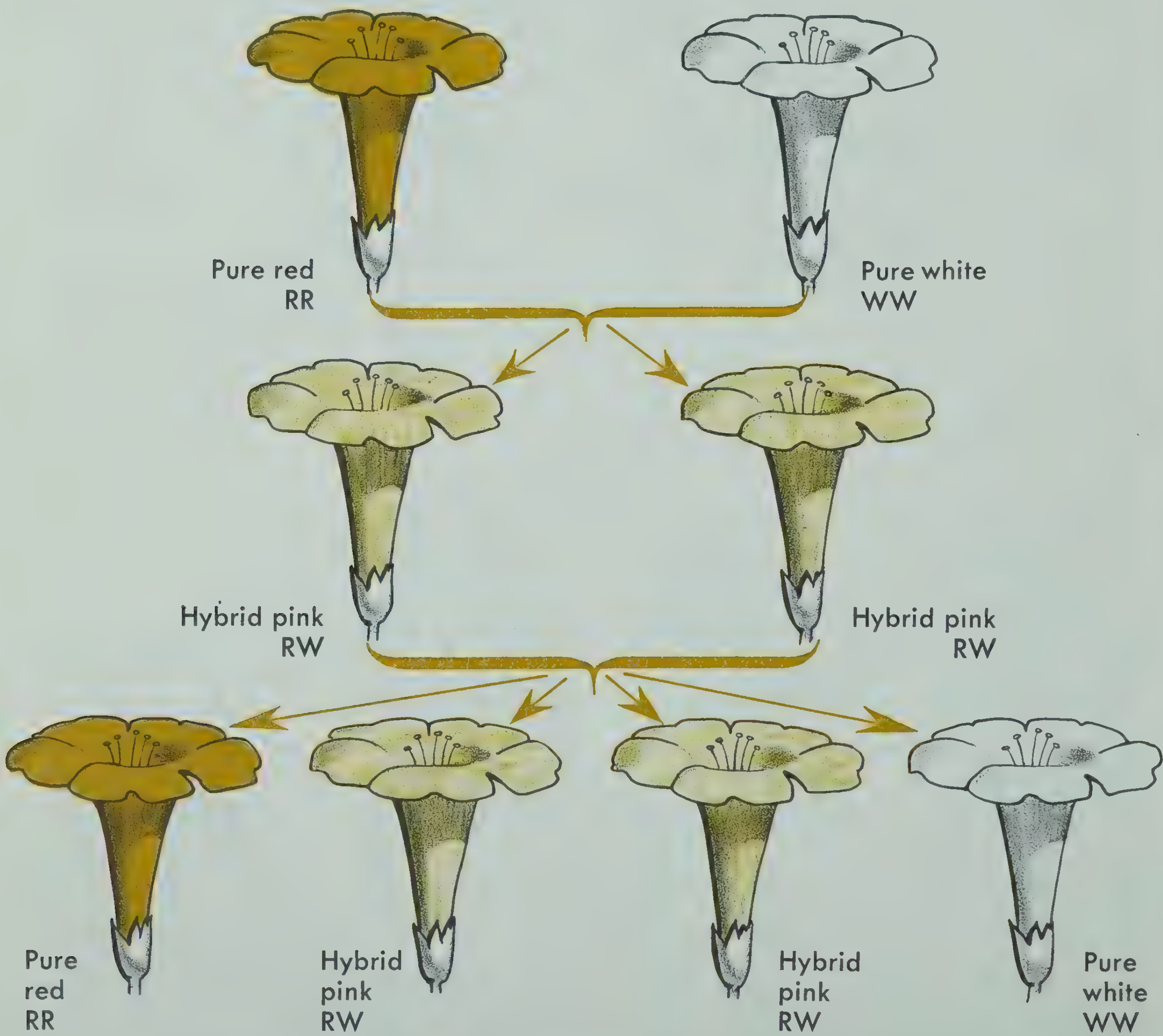
21–10. A cross between a pure dominant and a pure recessive pea plant. How does this cross illustrate Mendel's law of dominance?

inance, neither factor is dominant over the other. Look carefully at Fig. 21–11. What happened when two hybrid pink flowers were crossed?

Some dominant and recessive traits are shown in the table on page 487. In this table, you see that ***albinism*** (*al*-bun-*izm*) is a recessive character in man. It is a condition in which normal pigment is lacking in the skin, eyes, and hair. On the other hand, a condition in which the individual has extra fingers or toes is a dominant character.

Complex cases of inheritance. All characters of man and other organisms appear to be inherited according to Mendelian law. But unfortunately, some cases of Mendelian inheritance are rather complex. A ready example is furnished by human skin color. In this case, a number of gene pairs are involved. Each combination produces a different shade of skin color.

Several pairs of genes appear to affect human eye color. To some extent, however, these genes operate independently of one another. A human albino, for instance, has pink or reddish eyes. Study the chart of dominant and recessive traits at the top of page 486.



21–11. How do these crosses illustrate incomplete dominance?

SOME DOMINANT AND RECESSIVE TRAITS

Organism	Dominant or partly Dominant character	Recessive Character
Canary	Crested head	Plain head
Cattle	Hornless	Horned
Cotton	Colored lint	White lint
Fruit fly	Normal wings	Almost wingless
Fruit fly	Red eyes	White eyes
Guinea pig	Black fur	White fur
Man	Farsightedness	Normal
Man	Normal pigment	Albinism (no pigment)
Man	Brown eyes	Blue eyes
Man	Webbed fingers	Normal fingers
Man	Abnormally short fingers	Normal fingers
Man	Extra fingers or toes	Normal fingers or toes
Pea	Yellow seeds	Green seeds
Pea	Smooth seeds	Wrinkled seeds
Pea	Red flowers	White flowers
Silkworm	Yellow cocoon	White cocoon
Snapdragon	Red flowers	White flowers
Sunflower	Branched stem	Unbranched stem

A PROBLEM OF ALBINISM

Albinos appear among a number of animal species. Let us assume that mature sex cells produced by one of these species at a given time are as follows:

1. Eighty percent of them carry the gene for pigment (*P*).
2. Twenty percent of them carry the recessive albino gene (*p*).

To represent what is likely to happen when random crosses take place in nature, we can proceed as follows. Select 80 colored beans to represent mature sex cells carrying the *P* gene. Select 20 white beans to represent mature sex cells carrying the *p* gene. Put

21–12. A rare albino opossum from Australia; it has pure white fur and pink eyes. (*Australian News and Information Bureau*)

	PP (normal)	Pp (hybrid, but normal)	pp (albino)
Totals			

all the beans in a bag, mix them up, and draw out pairs of beans at random. You can set up a data sheet like the one shown above to record your results.

Draw out all the pairs of beans, enter your results, and compare your results with those of other students.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How many PP combinations did you have? Pp combinations? pp combinations? How many pairs of beans represent albinos?
2. From your results, what would be the percentages of P genes and p genes in the next generation? How does this compare with the original percentages?

BETTER PLANTS AND ANIMALS

Knowledge of Mendel's laws has made it easier to develop "better" cultivated plants and domesticated animals. It is no longer necessary to use the slow process of mass selection. When you know Mendel's laws, you can predict what will happen.

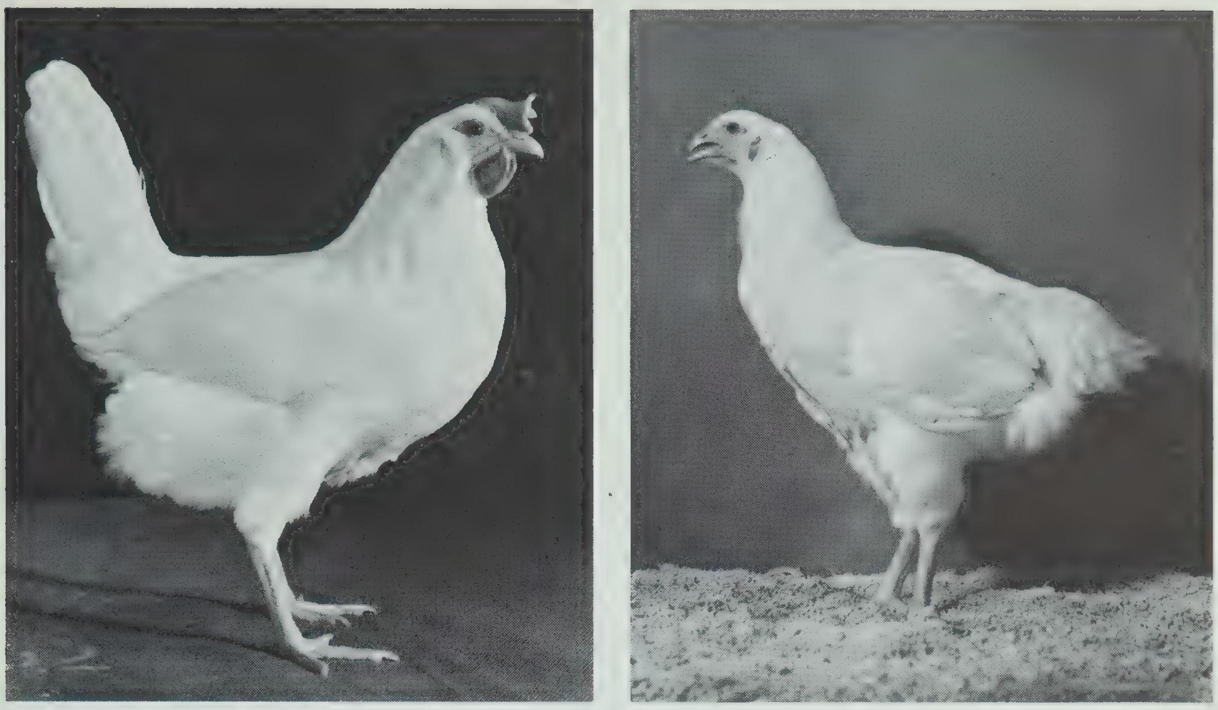
Desirable characters or traits. We desire a great variety of characters or traits in the plants and animals that we raise. In some cases, the search is for a type that is immune to a troublesome disease. Or, we may seek a variety of plant that matures rapidly, and will produce a crop in a land where the growing season is short. For example, a great many different wheat varieties have been developed. It is possible to select a variety that is well adapted to growing in almost any area, whatever the conditions of life may be.

Similarly, we want some animals that produce certain types of hair or fur. We want some plants that have certain kinds of leaves, stems, roots, or fruits. We seek special kinds of ornamental plants that produce flowers of various types and colors. Sometimes the urge is based on little more than a desire to have something new and different.

What is desirable depends upon what is in demand. For instance, you might suppose that people would prefer the biggest turkey they could get. This, however, does not always prove to be the case. Many families are better satisfied with the rather small Beltsville turkey which can be eaten at one sitting by a half dozen people. It is also a turkey that can be canned or quick frozen with relative ease.

Sources of useful characters. Scientists, who attempt to improve plants and animals, are always on the lookout for characters that may be in demand. Some of them travel to the far corners of the earth to study wild relatives of organisms that we raise. There is always the chance that some wild variety will have a much-sought trait, such as immunity to a disease.

There is also the possibility that a useful mutation will appear in a plant or animal species that we now raise. This has happened in the past, and



21–13. Animals are often raised for different qualities. Left, a white leghorn hen raised for laying eggs; right, a broiler or meat chicken. (*Grant Heilman*)

without doubt, it will happen again. Scientists even use X rays and chemicals to speed up the mutation rate of some organisms.

Tailor-made plants and animals. Once a useful character has been found, the plant or animal breeders go into action. Very likely, the character is possessed by an individual that has a lot of other characters that are not so desirable. But by using Mendelian methods in making crosses, it usually is possible to develop a variety that has the desired character, as well as other characters that are acceptable. In a sense, this is a case of developing a "tailor-made" plant or animal variety, and it is done quite often today.

If a desired character depends upon a single pair of genes, it may prove fairly simple to make this character a part of a "tailor-made" variety. Suppose, for example, that the desired character is red color, and that the opposed color is white. Let us also assume that red is recessive. Then *WW* is pure white, *Wr* is a hybrid that appears white, and *rr* is pure red and appears red.

This is the simplest case, because any individual that *appears* red has to be a *rr*. If the individual had even one *W* gene, it would be white. But suppose the *rr* individual is a mutant and the only one of its kind. The problem is still simple. You merely cross the rare *rr* with a number of *WW*'s. You get a group of offspring that are all hybrid for color (*Wr*). These *Wr*'s are white. But you now cross the *Wr*'s, and you have the following result:

		From one parent *W*	*r*
From the other parent	*W*	*WW*	*Wr*
	r	*Wr*	*rr*

So one out of every four offspring in this kind of cross appears red, and since

red is recessive, you know that all red offspring are *rr*'s. Now you begin to cross *rr* with *rr*, and get nothing but red individuals in future generations.

A test cross. But if the desired character is dominant, the problem is not so simple. Suppose red (*R*) is dominant and white (*w*) is recessive. A red individual appears as a mutation. This red individual may be either *RR* or *Rw*. What you need to start a new variety are two or more *RR*'s.

The first move is to make a test cross of the red individual with a white individual. You know that the white individual is a *ww*. If the red individual is *RR*, you get the following result:

		From the red parent *R*	*R*	
From the white parent	*w*	*Rw*	*Rw*	All offspring are red in appearance
	w	*Rw*	*Rw*	

But if the red mutant is a *Rw*, this is what happens:

		From the red parent *R*	*w*	
From the white parent	*w*	*Rw*	*ww*	Half of the offspring are red, and half are white
	w	*Rw*	*ww*	

Whatever the results may show, you now have some *Rw*'s that you can cross with other *Rw*'s. In these crosses, one out of every four offspring will be a *RR*. And you now have a way to find out which individuals are *RR*'s, rather than *Rw*'s. You simply cross all reds with whites, as in the preceding test. If no whites appear among the offspring, the red parent was *RR*. After you have identified a few *RR* parents, you are ready to produce a *RR* variety that will breed true.

Your ancestors might have done the same thing using mass selection. In this case, however, many years and many crosses would be necessary to get rid of all the *w* genes in the stock. When you use Mendel's laws, you get faster results. You have employed a process of *Mendelian selection.*

Hybrid varieties. Today, many of the flowers and vegetables that we raise are "tailor-made" hybrids. What this means is that the hybrid combines a number of desirable characters. We grow hybrid zinnias, marigolds, petunias, tomatoes, corn, and many others.

Hybrid corn serves as a good example of why special hybrids are in demand. A number of different hybrid corn types are now available. Some of them are field corns, and others are sweet corns. Each hybrid type has been developed to produce a special combination of characters. The general purpose, however, is to obtain a high yield of good quality.

Let us assume that four characters are desired in a hybrid type of corn. These characters are *A*, *B*, *Y*, and *Z*. You begin operations by making two kinds of crosses. In one cross *A* is combined with *B* in the new corn plants; in another *Y* is combined with *Z*.

Now you have two varieties of corn, and each of them has half of the characters you desire. So you make another series of crosses to combine *AB* with *YZ*. The seed you get from these crosses is what you want. It will produce plants that have all four of the desired characters.

The use of hybrid corn seed has increased yields greatly. Of course, production of the right kind of seed takes time and skill. The work has to be done by experts. You do not get *ABYZ* seed from *ABYZ* plants. You have to start all

over again and make the crosses that combine *ABYZ* in one hybrid seed. Even so, this has proved to be very worthwhile, in the case of corn and some other plants.

The advantage of a standard or nonhybrid variety of flower or vegetable is, of course, that seed production is no special problem. The plants breed true from year to year, unless mutations occur. You can gather seeds in autumn, and plant them the next spring. But you may have to be content with less satisfying products.

WORD MEANINGS

Number 1 to 7 on a sheet of paper in your notebook. Select the best answer for each of the following. Write it beside the corresponding number.

1. For many years, gardeners in the Brown family save and plant seeds of the best radish plants they produce. In time, they are raising an improved type of radish. The process they have used is called
   (a) variation. (c) mass selection.
   (b) mutation. (d) Mendelian selection.
2. A grasshopper begins life in a normal fashion, but one day it loses its left front leg. This change in the grasshopper's structure is a(n)
   (a) acquired character. (c) mutation.
   (b) hybrid character. (d) dominant character.
3. A certain plant bears white flowers. Its sex cells are acted upon by X rays so that their *DNA* molecules are changed. The offspring of this plant bear red flowers. This change in flower color is a(n)
   (a) acquired character. (c) recessive character.
   (b) dominant character. (d) mutation.
4. *BB* (brown) is crossed with *ww* (white). All of the *Bw* offspring are brown. This is an indication that the *B* gene is a(n)
   (a) mutant. (c) acquired character.
   (b) dominant. (d) recessive.
5. *RR* (red) is crossed with *ww* (white). All of the *Rw* offspring are pink. This is an indication that the *R* gene is a(n)
   (a) hybrid. (c) incomplete dominant.
   (b) recessive. (d) mutant.
6. Two black crow parents produce a young bird that has white feathers and red eyes. The evidence suggests that the young bird is a(n)
   (a) incomplete dominant. (c) hybrid.
   (b) albino. (d) dominant.
7. Tallness (*T*) is dominant and shortness (*t*) is recessive. You cross a number of *Tt*'s and produce 100 offspring. Seventy-five of these offspring are tall, 25 are short. How many are probably hybrids (*Tt*)?
   (a) 25 (c) 75
   (b) 50 (d) 100

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. For thousands of years, farmers have used Mendelian selection to improve their plants and animals.
2. Variation among the members of a species is the rule, rather than the exception.
3. What the individual inherits is determined by genes in the fertilized egg cell, from which the individual develops.
4. A human individual that has two X chromosomes is a male.
5. Environment has little or no effect in determining the characters of an individual.
6. An acquired character is represented by changes in body cells, but not by changes in sex cells.
7. The great majority of acquired characters are inherited.
8. A mutation is represented by changes in the genes of sex cells.
9. It is quite possible for a mutation to be inherited.
10. Most mutations prove useful to the species that develops them.
11. Mendel's Tt peas were just as tall as his TT peas.
12. In Mendel's peas, the t gene was recessive.
13. A dominant gene is completely dominant over the opposed gene.
14. If you cross a red four-o'clock flower with a white four-o'clock flower, the offspring will bear pink blossoms.
15. All characters that we inherit are determined by a single pair of genes.
16. Albinism is a condition in which animals lack a normal amount of pigment.
17. Cultivated wheat is represented by many different varieties today.
18. If red (R) is dominant and white (w) is recessive, you know that any white individual is ww.
19. You can collect the seeds from a hybrid plant and use them to produce another crop of the same type.
20. The only hybrid plant we raise today is field corn.

DISCUSSION QUESTIONS

1. Explain why important discoveries are not always recognized as such at the time they are made.
2. Why do we often fail to observe variation in the plants and animals around us?

3. What is the relationship of *DNA* molecules to the genes of sex cells?
4. How is sex determined in the case of man?
5. What two general forces act to produce differences among the individuals of a species?
6. What are some ways in which an organism is likely to develop acquired characters?
7. What are mutations, and what causes them?
8. Why does a harmful mutation, that causes early death, have no lasting effect upon the species?
9. Explain how it is possible for a mutation to be desirable in an animal that we raise, but undesirable if the animal lived in the wild state.
10. Explain how it is possible for an individual to be a hybrid for one character, but not a hybrid for another character.
11. Red (*RR*) is dominant and white (*ww*) is recessive. If *RR* is crossed with *ww*, what percentage of the offspring will be red? What percentage will be hybrids for color?
12. Why do you think that an albino animal, such as a white rat, might be at a disadvantage, if it lived in the wild state?
13. What sort of traits do we seek in our efforts to improve plants and animals?
14. Why is Mendelian selection superior to mass selection in producing new plant and animal varieties?
15. What is a test cross, and how is it used?
16. Why would the farmers of North America wish to have more than one type of hybrid corn?
17. Do we always prefer the biggest fruit, vegetable, or animal? Explain.

THINGS TO DO

1. Prepare a bulletin board exhibit to show variation in the structures of some plant. Flowers, seeds, and leaves may be used. Leaves of the sassafras tree will show a great deal of variation.
2. Have a partner, you are working with, mark off a half-inch square on the back of your left wrist. Do the same for your partner. Using a fine-pointed scissors, snip off all the hairs that are rooted in the half-inch square. Collect the hairs on a piece of paper and count them. Compare your result with that of your partner and other students.
3. Sprout a dozen radish plants in each of two trays, but under different conditions, as follows:

   Tray A. Good loam soil that is kept moist, but not wet. Good light supply.

Tray B. Soil that is half loam and half sand. Soil partly dry most of the time. Only fair light supply.

The purpose of this study is to compare the effects of favorable environment and unfavorable environment. Keep records of what happens for a period of about three weeks.

4. Assume you have a population in which *BB* is blue, *Bw* is gray, and *ww* is white. In this case, *B* is incompletely dominant over *w*. Suppose you start with a group containing 20 *BB*'s and 80 *ww*'s. What is the next generation likely to be? Use the bean-pair method, described on page 487, to determine your results.
5. Obtain a seed catalogue. Prepare a list of the different varieties of (a) marigolds, (b) zinnias, (c) sweet corn, and (d) tomatoes listed in the catalogue. Note the most important facts about each variety, including whether it is a standard or hybrid type.

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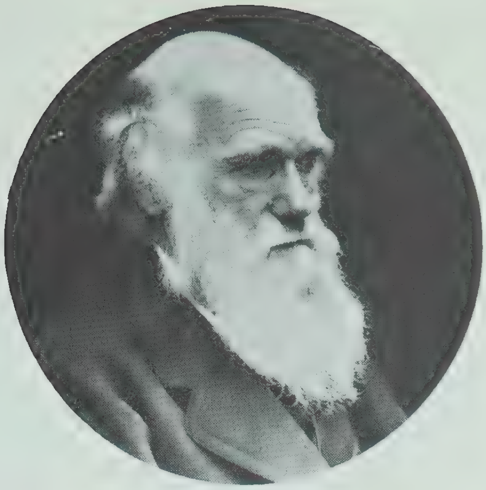


CHAPTER 22

Natural Selection

During the millions of years that life has existed, fossils of former plants and animals have been preserved in the rocks. You may wonder how this comes about, but actually, the process is quite simple.

THE FOSSIL RECORD

At this moment, in fact, new layers of rock are being formed in various parts of the world. The hard parts of dead plants and animals are being preserved in some of these rocks.

Rocks and fossils. As an example, let us consider what is happening at a point where a river empties into the sea. The waters of this river are carrying sand and mud particles. When these waters mingle with the sea, there is no longer any river current. Many of the sand and mud particles now drop to the bottom. Little by little, a layer of sand and mud is built up. In time, other layers will be formed. The deposit may become many feet in thickness.

While this is going on, oysters and clams live and die on the sea bottom. Their hard shells are covered by the layers of mud and sand. At the same time, the lower layers of mud and sand are being pressed together and made more solid. The pressure to do this comes from the weight of other layers of mud and sand that have piled up above them. Years pass, and the compressed layers of mud and sand have solidified and become rock. In this rock are the fossils that represent the oyster and clam shells.

The scientists, who study rocks and fossils, know the ages of many rock layers. They may know, for example, that rock layer *A* was formed 10 million years ago, and that rock layer *B* was formed only 10,000 years ago. So they are able to say that the fossils in these layers represent plants and animals that lived in certain places at certain times.

The table on page 496, shows five eras in the earth's history, and the types of living things that were dominant in

these eras. Note the great length of time included in some of the eras. Many of the species, that were common a half million or a million years ago, no longer exist.

An age of invertebrates. Locate the Age of Invertebrates in the Paleozoic Era. It began about a half billion years ago. At this time, the dominant animals were invertebrates that lived in the warm, shallow seas. Among them were sponges, corals, and mollusks. These ancient species are long since extinct, but other species that replaced them have continued to live on into the modern era.

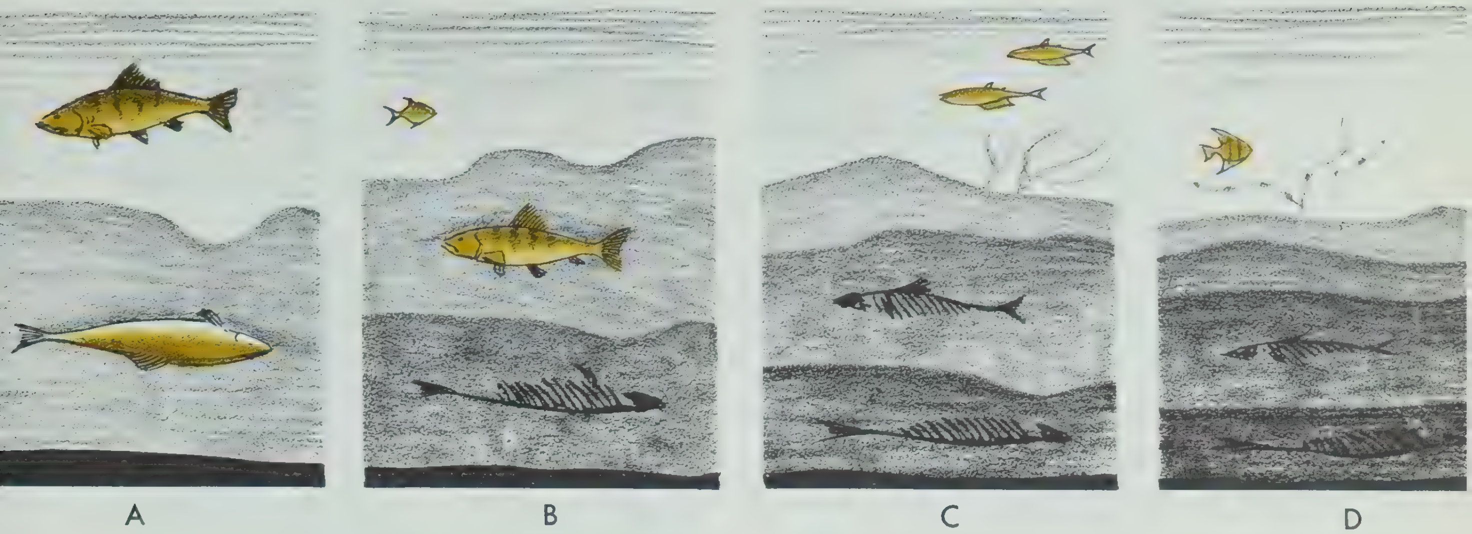
An age of fishes. Next came an Age of Fishes, and during this period ancient fish types dominated the shallow seas. These fish were early representatives of the vertebrate line. From some of them, swamp and land-dwelling forms developed as time went on. These land-dwelling animals became the ancestors of the amphibians and reptiles.

An age of amphibians. Amphibians succeeded the fish as the dominant form of animal life. During this period, vast swamps existed. Land plants had appeared, and species similar to modern horsetails and club mosses, grew abundantly in the swampy areas. Large coal deposits were formed from the remains of plants that died and were buried in the mud and ooze. Primitive insects were also present in and about these ancient swamps.

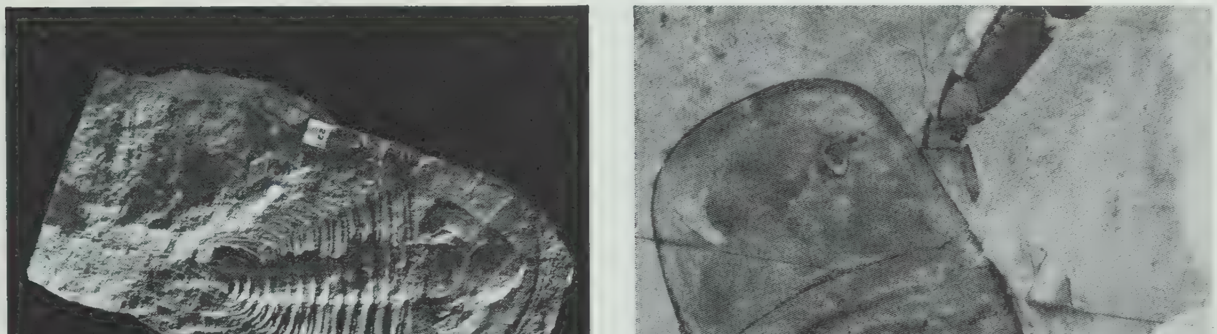
An age of reptiles. As the Age of Amphibians came to an end, there were

LIFE IN PAST ERAS OF TIME

Era	Length of Era	Dominant Life Forms	New Types
CENOZOIC	60 million years	Man Mammals Flowering plants	
			Flowering plants
MESOZOIC	140 million years	The Age of Reptiles	Birds Mammals
PALEOZOIC	300 million years	The Age of Amphibians	Reptiles Amphibians Insects Land plants
		The Age of Fishes	Fish
		The Age of Invertebrates	Many invertebrates
PROTEROZOIC	500 million years	Protists and other simple organisms	
ARCHAEOZOIC	One billion years	Unknown life	



22–1. Fossil formation in a streambed. (A) A dead fish is buried in the sediment. (B) Another fish is buried, mineral matter enters the bones of the first dead fish. (C) In time the bones of both fish are replaced by minerals. (D) Many sediment layers are built up over thousands of years.



22–2. A group of fossils embedded in stone. Identify the fossil outline in each photograph. (*The American Museum of Natural History*)

marked changes in the earth's climate. It had been warm and humid, but now it became cold and dry. The new climate probably did not favor most of the amphibians. Protected by their armor of scales and plates, reptiles were more likely to survive. These reptiles became the dominant forms of animal life for about 140 million years. Some of them were quite small, but others included dinosaurs that probably weighed up to 50 tons. Among these reptiles were some types that ate flesh, and other types that subsisted on plants.

During this era, some early mammals were developed from the ancient reptile stock. The first birds also came from reptile ancestors. One of these birds was about the size of a crow. You see a reproduction of it in Fig. 22–3. This early bird had feathers, but note how they were arranged on either side of its reptilian tail. Note also the free claws on the wings. The bird had a beak, but the beak was armed with teeth.

During the Age of Reptiles, flowering plants became common on the land. When the era ended, the stage was set for the expansion of modern life forms: flowering plants, mammals, and birds. But first, many of the reptiles had to go, and we have already indicated that scientists are not sure just how and why this came about.

22–3. Left, fossil *Archaeopteryx,* one of the first birds. Right, a drawing of *Archaeopteryx* made from the fossil. (*American Museum of Natural History*)

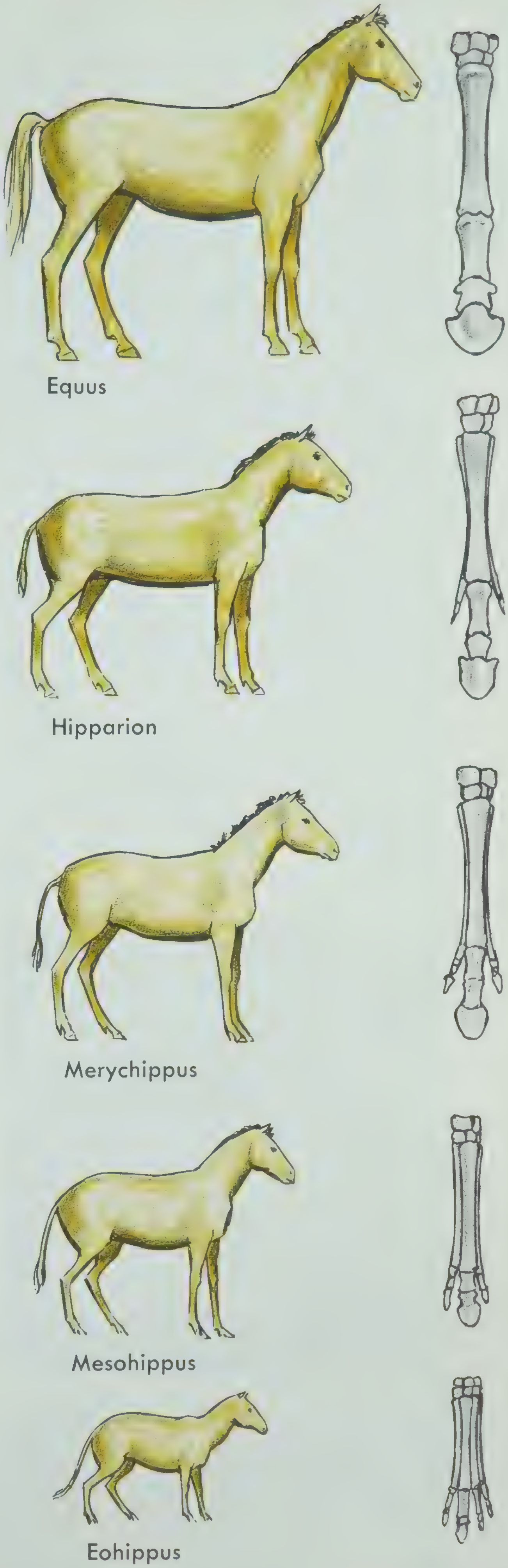
An age of mammals. The first mammals were small, and probably were no match for some of the flesh-eating reptiles of their world. Perhaps they survived, because they were able to take refuge in burrows or crevices in the rocks. As the reptiles died out, these mammals and their descendants increased in numbers and in variety. They became the dominant form of animal life on the land.

The fossil history of some mammals is well known. The horses shown in Fig. 22–4, for example, arose in the early part of the Age of Mammals. They were much smaller than modern horses, and instead of hooves, they had four toes. As time went on, a larger type of horse with three toes developed. It was, in turn, replaced by a still larger horse that had a hoof developed from the single middle toe. This type of horse was similar to the horses we raise today.

The fossil record. The fossil story is one of change. Living things have existed for millions of years. During this period of time, many new species have appeared. Many other species have died out. The only real question is the question of *how* the new types of plants and animals have been developed. How can a reptile give rise to an animal like the toothed bird in Fig. 22–3?

THEORIES ABOUT NEW SPECIES

Theories about changes in plants and animals existed in ancient times, but were not very well developed. One



22–4. Stages in the evolution of the horse. Early horses were much smaller than modern horses, and they had four toes. Eventually, the modern horse evolved.

poet of Ancient Rome did speak of a "struggle for existence and survival of the fittest."

Buffon and Lamarck. This idea of a "struggle for existence" appears again in the writings of Buffon, an eighteenth century Frenchman. Buffon also noted that variation existed among the members of a species, and that there was such a process as heredity in nature. Buffon, however, gathered little evidence to prove his points.

Shortly thereafter, another Frenchman, named Lamarck, proposed a theory to explain the origin of new plant and animal types. In this theory, Lamarck assumed that acquired characters could be inherited. Thus, if giraffes stretched their necks to eat the leaves of trees, the necks would become longer from generation to generation. In the end, modern giraffes with very long necks would be the result.

This theory of Lamarck was opposed by some of the scientists of his own day. They could not *prove* that

22–5. According to Lamark's theory, how did this giraffe come to have a long neck? (*Dave Thornton from National Audubon Society*)

22–6. H.M.S *Beagle,* the ship Darwin used to make his explorations. (*American Museum of Natural History*)

Lamarck was wrong, but they seemed to feel that his ideas were not very sensible. Here matters rested, until the middle of the nineteenth century.

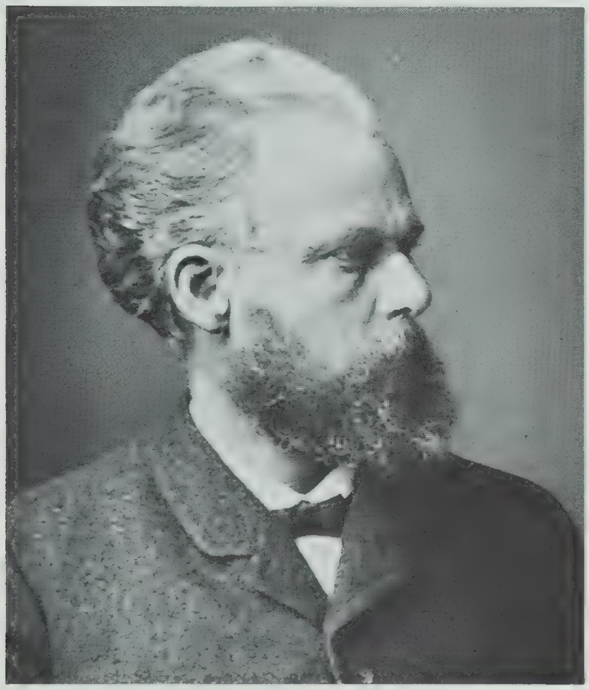
Darwin and Wallace. Charles Darwin was born in England in 1809. Early in life, he became interested in the study of plants and animals. As a young man, he made a long sea voyage on H.M.S. *Beagle,* going ashore to study plants and animals in many parts of the world. While visiting islands off the west coast of South America, he made an interesting observation. He noted that the species found on these islands were often *similar* to species on the nearby mainland, but that they were also somewhat *different.* Darwin began to give more and more thought to the causes of such differences.

Darwin spent many years studying a variety of plants and animals. He studied pollination in flowers, the habits of earthworms, the formation of coral reefs, and many cultivated plants and domesticated animals. Finally, he was about ready to announce his theory

of *natural selection.* The purpose of this theory was to explain how plant and animal species changed.

On the other side of the world, another scientist named Alfred Russel Wallace was also observing many plants and animals. He had developed a theory that proved to be very similar to Darwin's theory of natural selection. The theory, however, is generally credited to Darwin, because he had collected so many evidences to support his ideas.

Weismann and inheritance. You will read about natural selection in the next section of this chapter. The modern version of this theory is similar to that of Darwin, but there is one notable difference. Apparently, Darwin was aware that not all variations were inheritable. But he was unable to distinguish between the inheritable group and the noninheritable group. This distinction had to wait until August Weismann, a German, made it in the latter part of the past century. At the time, some biologists thought there might be a certain amount of truth in Lamarck's ideas. Weismann decided to test these ideas.



22–7. August Weismann, the biologist, experimented with mice in order to prove his theory that acquired characteristics were not inherited. (*New York Public Library*)

Weismann started an experiment with a group of young mice. He cut off their tails as a simple way to give all of them the same acquired characteristic. Then the mice were fed and housed until they produced offspring. Weismann removed the tails from these offspring, and so the experiment continued until it included 1592 mice in 22 generations. According to Lamarck's ideas, the mice should have developed shorter tails as a result of their experiences. This, however, did not happen. A final generation of mice was permitted to grow tails. The tails were normal in length.

Weismann made other studies that were largely concerned with reproduction. He denied the inheritance of acquired characteristics. He pointed out that there is no mechanism whereby a change in a body cell can be transferred to a sex cell. Weismann believed that natural selection would work well enough without any inheritance of acquired characteristics.

DeVries and mutations. As the present century began, a Dutchman named Hugo DeVries published his *mutation theory.* DeVries had been studying the evening primrose, an American plant that was growing wild in the fields of Holland. He believed that he had observed the sudden appearance of several *large variations* in this species.

DeVries called these large variations "mutations." His theory held that every now and then a species went through a period in which such "muta-

tions" were produced. These large variations accounted for the development of new species, because the variations were inheritable.

It developed, however, that the primroses DeVries had observed were hybrid types. The "new" characters that appeared may not have been new at all. Some of them may have been represented in evening primroses for many generations. If they were caused by recessive genes, the "new" characters would only appear in occasional individuals.

So what DeVries observed probably was not what he thought it was. But now and then a large mutation really does occur, as in the case of the ancon sheep, described in Chapter 21. We now use the term mutation when we refer to *any new character that can be inherited.* Most of these mutations are rather minor in nature.

22–8. In nature, there is a constant competition and struggle for existence. The weeds in this picture are in competition with other plants. (*Grant Heilman*)

FITNESS AND SURVIVAL

In trying to answer our question of how plants and animals change, we must turn to the study of plants and animals as we find them today. They live in communities, and one of the key factors in community life is *competition.* The plants you set out in a flower bed seem mild and harmless enough, yet if they grow close together, they are in competition for soil moisture, minerals, and sunlight. The weeds that spring up among them are also competitors. If the weeds are allowed to remain, they will soon take over, at the expense of the cultivated plants.

Even the soil beneath your feet is a battleground in which millions of small organisms are in a constant state of quiet combat. In the surface soil, the most common forms of life are the bacteria, but millions of fungi are also present, as well as smaller numbers of protozoa and algae. Worms, insects, crustaceans, and some higher forms of life also inhabit the soil. Several tons of organisms may be present in the soil of a single acre of land.

All of the food groups are represented among these soil organisms. Various food chains are in operation. Savage contests take place, as one small organism devours another, or a group of parasites attacks a host. Meanwhile, the many bacteria of decay and some of the fungi feast upon the remains of organisms that have failed to survive.

So nature may appear to be "mild," but this appearance is somewhat misleading. In earlier studies, you have learned that the death rate among many kinds of organisms is very high. Millions of spores, seeds, and eggs are produced every year, but very few of them are likely to develop into adult organisms. If a large proportion did

survive, there would soon be serious overcrowding.

The struggle for existence. Every individual organism has two basic needs: to eat, and to avoid being eaten. The plants and the lower types of animal life do not worry about such problems, because they are incapable of thought. But their needs are no different than the needs of other organisms. They must have foods or the materials from which foods are made. They must also escape destruction.

Competition exists among the members of a community at all times. Even the young rabbit that nibbles white clover at the edge of a field is a competitor. The rabbit supplies its food needs at the expense of the white clover population. And the rabbit is not secure by any means. A prowling fox may pounce upon it at any moment. Or, the rabbit may be the host of parasites that have gained entrance to its body.

Since there is this competition for food and survival, we may think of the result as a *struggle for existence*. To win out in this struggle, the rabbit must have its clover. It must find refuge from the fox. It must avoid dangerous parasites.

The survival of the fittest. At this point, we should recall the fact that members of a species vary. One rabbit can run faster than another rabbit. One fox is a better hunter than another fox. One wild duck is more alert to danger than another wild duck.

In view of this variation, and the high death toll in nature, biologists believe that the fittest individuals tend to survive. Of course, some fit individuals are "unlucky" now and then; they are destroyed, because they happen to be in the wrong place at the wrong time. But since we are dealing with large numbers, the loss of a few fit individuals does not change the result very much.

Natural selection. The process in which the fit tend to survive is called *natural selection*. As part of the process, individuals which have defects of one kind or another are likely to be eliminated. A defect in this case is any character that tends to make the individual a poor competitor. A bird with a defective wing, for example, would be handicapped in obtaining food and in escaping from its enemies.

The fit individuals that do survive are the ones that produce the next generation of offspring. They pass on to the offspring various characters that make for fitness in a particular environment. An *acquired* character would not, of course, have any part in this process. Acquired characters are not inherited, even though some of them may prove to be useful. The characters that are passed on are the characters represented in the *DNA* of sex cells. They include any new mutations that may occur.

In summary, the modern view of natural selection recognizes that variation exists among the members of a species. A struggle for existence takes place, and the more fit individuals tend to survive. These survivors pass on to the next generation various hereditary characters that made their success possible.

Changes in populations. As the environment changes, populations change also. Certain species are favored today, but tomorrow other species will have the advantage. So you see that the conditions of life really determine what fitness is.

For instance, at a given time and place, fitness of a certain plant may be

the ability to grow tall and reach the sunlight. So the tallest plants of this species tend to survive. The average height of the species increases. But this increase is limited by what the individual plants inherit. Before height can increase beyond this limit, a mutation that produces a taller variety must take place. Then the average height of the population can increase again.

But be sure to note an important fact. Mutations do not occur just because they are needed. A plant that might profit by being taller may be doomed to remain as it is. Mutations are *chance* variations. The desirable mutation does not occur just because it is needed.

You can see that natural selection is a good deal like the selection we use to improve our plants and animals. But there is a difference also. In natural selection, the nature of the environment determines the characters that will be useful. In the case of plants and animals that we raise, man determines the types that shall survive. Sometimes this man-directed process is called *artificial selection*. Certainly, it is artificial in the sense that various characters we prefer in our plants and animals might not help them to survive in the wild state.

THE DISTRIBUTION OF ORGANISMS

Each species of plant and animal has a homeland where it first existed. But various members of the species have usually moved into other areas that may be nearby in some cases, and far away from the homeland in others.

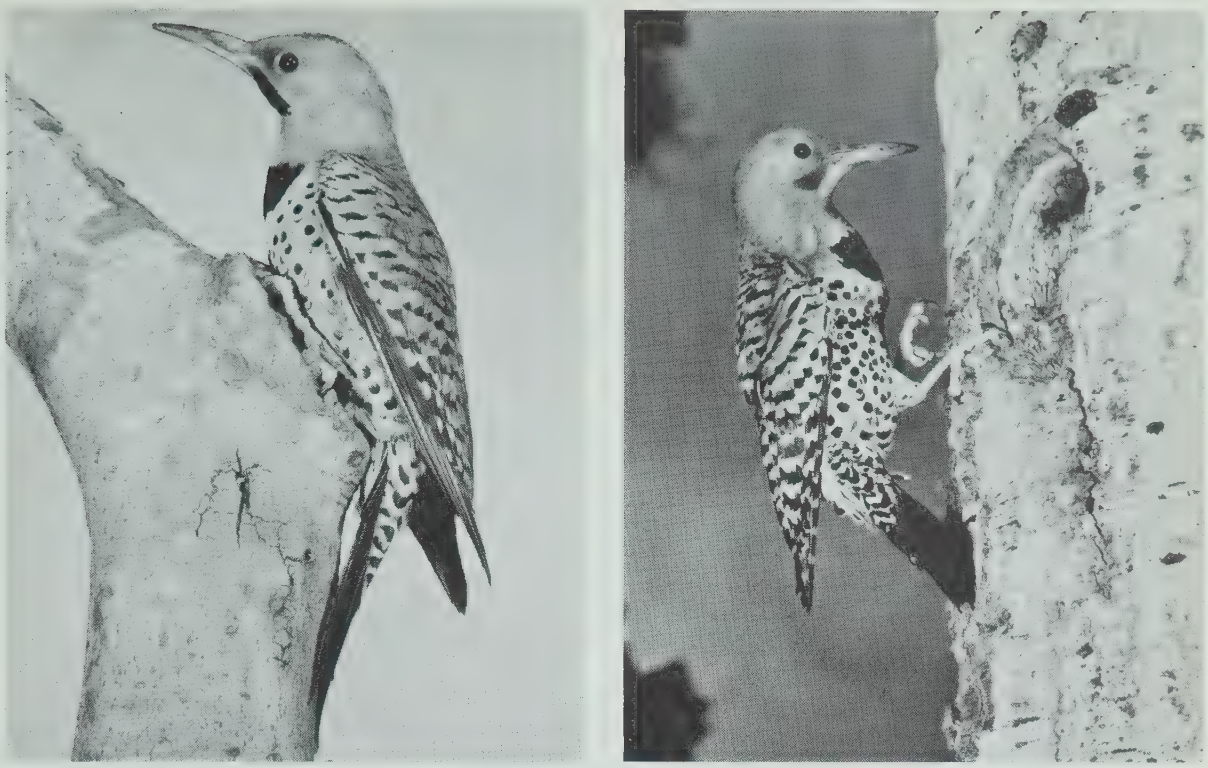
Nature of dispersal. The process in which a species spreads out over the surface of the earth is called ***dispersal.*** The manner in which dispersal takes place is closely related to survival and natural selection.

You have read how some types of spores and plant seeds are carried long distances by the wind. Simple plants that live in the water can be transported by water currents, and so can some plant fruits and seeds. Wandering animals also carry certain plant fruits and seeds. Various land animals can crawl, walk, or fly. Animals that live in the water can often swim. Even an oyster, which grows fastened to some object on the bottom, has a free swimming stage in the early part of its life cycle.

We may also note that man has been an important agency in the dispersal of many species. For one reason or another, man has transported a large number of plants and animals to all of the places that he inhabits. Often this has been done by accident, rather than intent.

Dispersal and selection. The present distribution of any species depends upon (a) its place of origin, (b) how effectively it has been dispersed, and (c) its ability to survive in the new communities it has invaded. The old idea that each species occupies the area to which it is best adapted has proved to be untrue. When we transport a plant or animal from one area to another, we sometimes find that it prospers greatly in the new home. Thus, English sparrows and starlings, which once were confined to the Old World, have become very numerous in North America.

Adaptation and survival. The degree to which a species is adaptive is naturally very important. You could not imagine an anteater faring very well in



22–9. Left, the red-shafted flicker of western United States; right, the yellow-shafted flicker of eastern United States. It is thought that at one time there was one common ancestor of these birds. The development of the treeless Great Plains in the central United States caused isolation of this bird population. Genetic changes within the population have resulted in the traits we observe today. (*Left, Allan D. Cruickshank from National Audubon Society; right, Karl H. Maslowski from Photo Researchers*)

a community where the only abundant foods were fruits, seeds, and grasses. And you do not find anteaters far removed from their homeland, unless they are in zoos.

On the other hand, the house rat has proved capable of surviving in many different communities. Evidently, it began its existence in Asia. From this area, it has been dispersed to most parts of the world. The house rat is clearly a very adaptive animal. You can easily see some reasons why this is the case. For one thing, the house rat is an omnivore: it can find food where almost any plant or animal material exists. For another, the house rat takes refuge in burrows. Burrows provide protection against natural enemies, and also against extremes of heat and cold.

Among the plants that we raise, wheat has proved to be quite adaptive. There are types of wheat that prosper in the warm lands, and others that grow successfully in cold countries. There are also types that produce crops on fairly dry soil. This is perhaps the main reason that wheat is the world's number one grain crop.

It is not, then, a case of each species living in the areas to which they are best adapted. You find them living where they have proved sufficiently fit or well adapted to survive. In some cases, these areas are limited to the homelands. In others, they include areas to which the species have become dispersed. In either case, the species are always subject to the continuing action of natural selection.

WORD MEANINGS

Number 1 to 8 on a sheet of paper in your notebook. Select the best answer for each of the following items and write it beside the corresponding number.

1. Hard parts of plants and animals that have become part of a rock layer are known as
   (a) remnants.
   (b) artifacts.
   (c) fossils.
   (d) records.
2. In the following list, the period in which sponges, corals, mollusks, and similar animals were dominant was the
   (a) Age of Amphibians.
   (b) Age of Mammals.
   (c) Age of Fishes.
   (d) Age of Invertebrates.
3. In the following list, the only inheritable character would be the case in which
   (a) a blacksmith developed a strong right arm.
   (b) a plant mutation resulted in a new flower color.
   (c) a rat had its tail cut off.
   (d) a tree on a hillside developed a stunted growth.
4. The scientist who developed the mutation theory was
   (a) Lamarck
   (b) Buffon
   (c) Weismann
   (d) DeVries
5. When fit individuals survive and pass on the characters that made them fit, to their offspring, the process is called
   (a) a struggle for existence.
   (b) the inheritance of acquired characters.
   (c) natural selection.
   (d) competition.
6. In artificial selection, fitness is determined by
   (a) human choice.
   (b) physical factors of the environment.
   (c) competition among different species.
   (d) the basic food supply.
7. When the members of a species move out of the homeland into new areas, the process is called
   (a) migration.
   (b) dispersal.
   (c) spreading.
   (d) selection.
8. A species that can survive under a wide range of living conditions is said to be
   (a) prolific.
   (b) tenacious.
   (c) agressive.
   (d) adaptive.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The fossil record indicates that the first living things on earth appeared about 10 million years ago.
2. The first living things probably were protists and other simple types of life.
3. The amphibians are believed to have descended from some of the fishes.
4. The first fossil birds were without teeth.
5. Various small mammals came into existence during the Age of Reptiles.
6. Lamarck was strongly opposed to the idea that acquired characteristics could be inherited.
7. Charles Darwin is generally credited with developing the theory of natural selection.
8. Weismann denied the inheritance of acquired characters.
9. DeVries developed his mutation theory as a result of studies in which he used white rats.
10. Plants growing close together compete with one another for soil moisture, minerals, and sunlight.
11. Most of our topsoils contain very few plants or animals.
12. In nature, fitness depends upon the existing conditions of life.
13. If an acquired character makes an individual fit for survival, this character will be passed on to the offspring by heredity.
14. When environments change, populations of plants and animals change also.
15. In natural selection, the nature of the environment determines whether a given character is harmful or useful.
16. Artificial selection refers to methods we use to improve our cultivated plants and domesticated animals.
17. Some species are dispersed because they are accidentally transported by man.
18. Place of origin has very little to do with the present distribution of any species.
19. All species are about equally able to survive in different environments.
20. Some species have become much more widely dispersed than have other species.
21. A species is not affected by natural selection so long as it remains in its homeland.
22. The house rat has the ability to adapt to many different environments.

DISCUSSION QUESTIONS

1. Do you think that any fossils are being formed at the present time? Give your reasons.
2. How old are the rocks in which the first fossils appear?
3. Did the earliest forms of life live on land, or in the water?
4. From what animals are reptiles descended? Birds? Mammals?
5. Under what conditions are coal deposits formed? How are plants related to this process?
6. When did the first mammals appear? When did they begin to dominate life on the land?
7. Was the "struggle for existence" an original idea with Charles Darwin? Explain.
8. Why did Weismann deny the inheritance of acquired characteristics?
9. What was rather odd about DeVries' mutation theory?
10. What do we mean when we say that there is a great deal of competition in nature?
11. How is the modern version of natural selection supposed to operate?
12. How do you explain the fact that communities are in a constant state of change?
13. What kinds of organisms are you likely to find in the surface soil?
14. Why do you think that a struggle for existence takes place in nature?
15. In a state of nature, what determines the characters that make an individual better able to survive?
16. What are the steps in the process of natural selection? How does it differ from artificial selection?
17. How do various types of plants and animals become dispersed?
18. On what factors does the present distribution of any plant or animal species depend?
19. Why have some species become much more widely dispersed than others?
20. What do we mean when we say that a species is highly adaptive? Give an example.

THINGS TO DO

1. If a fossil-bearing outcrop of rock is nearby, collect some specimens. See if you can discover what types of life they represent. You may also be able to find out the era in which the rocks bearing the fossils were formed.
2. If a museum of the right type is available, arrange a museum trip. Study the fossil remains and restorations of prehistoric plants and

animals. Compare these ancient types with similar types that exist today.

3. After consulting the references listed below, prepare a report on animals that have either become extinct or greatly reduced in numbers within the past thousand years.
4. Use pictures and drawings to prepare a bulletin board exhibit showing types of life that existed during the Age of Amphibians and the Age of Reptiles.
5. Look up horsetails and club mosses in an encyclopedia. Prepare a report on the giant relatives of these plants that lived millions of years ago in the old coal swamps.

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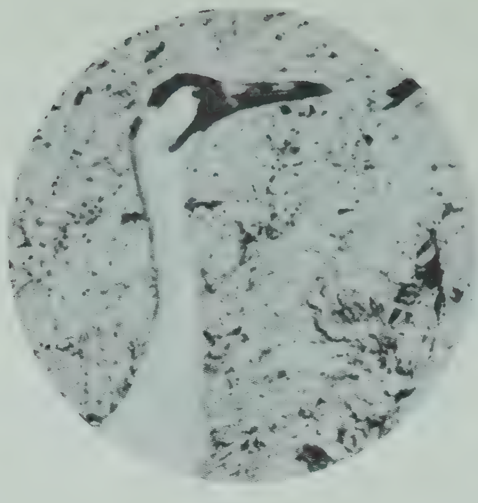


CHAPTER 23

Man and the Balanced Community

You may tend to think of the natural community as a place untouched by human hands. But this is by no means true. Man has moved into natural communities all over the earth's surface. He has become a part of these communities, and has modified them to suit his needs. Certain species of plants and animals are favored by man's presence, but others are not so fortunate.

While natural selection is a process that we do not direct, it is greatly influenced by many of our acts. For wherever men live, they bring about changes in the environment. Such changes may determine the nature of fitness. You now know that an organism must be fit in order to survive.

WILDLIFE

The native populations of a community make up its *wildlife.* Let us consider what happens to the wildlife of a forest community when man moves in. Before man arrives on the scene, wildlife has managed to survive, because (a) it has been able to obtain food in the forest habitat, and (b) the forest has provided necessary *cover.* Cover means places where animals may find refuge from their natural enemies. Thus, a hollow tree provides cover for a squirrel.

Note also that the wildlife of a forest is made up of species that are adapted to life in the forest habitat. In a prairie community, you would find different organisms that are adapted to living on the grasslands. The prairie animals eat different foods, and they use different kinds of cover. Prairie plants are adapted to different conditions of growth.

Effects upon wildlife. When man moves into the forest community, one of his first acts may be to cut down the trees. From man's standpoint, this is

necessary. Fields are needed to raise crops, so the trees must go. As the trees are felled, food supplies and cover for forest animals are reduced. Some animals may retreat back into forested areas. Other species may begin to die out.

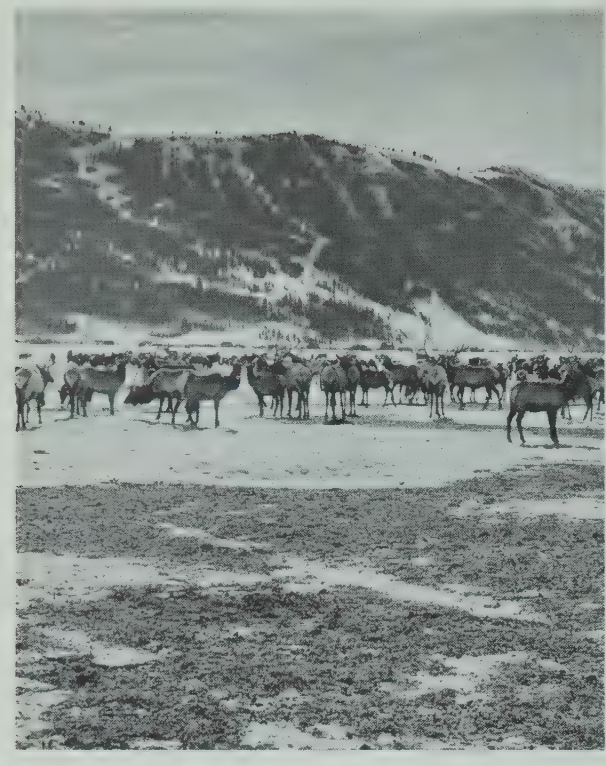
The overall effect depends, however, upon the way in which the land is cleared. If all trees and bushes are cut away, the forest animals are doomed. No suitable food or cover remains. On the other hand, if some woodlots are left on the hillsides, and if some bushes and small trees are allowed to grow along fence rows, the effect on wildlife may be much less damaging. Now there are some wild fruits, nuts, and buds that provide food. There is also some cover. So at least a part of the original wildlife can survive. Other forms of wildlife will move into the area. They will probably be species adapted to life in a more open country.

Wildlife in other communities. The case of a prairie community is similar to that of a forest. When the prairie is replaced by fields, natural foods and cover tend to disappear. Some native species continue to prosper, but other species decline in numbers. Some new species may move into the area. But in this case also, if native food-producing plants remain along fence rows and on rough ground, there will be some food and cover for wildlife.

We have already discussed freshwater communities and the effects of stream pollution. When streams are polluted by sewage and untreated factory wastes, native fish no longer have an environment in which they can survive.

The importance of wildlife. It has taken a long time for us to realize that wildlife is an asset. But the people who live in and about our great vacation lands now know that this is true. Fishermen do not spend their vacations in

23–1. Forest destruction can be caused in a number of ways: Left, a forest being cleared for the building of a dam; right, the results of a forest fire. (*Left, American Forest Products Industries; right, Standard Oil Co., N.J.*)



23–2. Winter feeding grounds for elk herds at the Wildlife Refuge, Jackson Hole, Wyoming. (*Ray Atkeson*)

23–3. The praying mantis is a very important biological control. It destroys many harmful insects. (*George Roos from Photo Researchers*)

places where there are no fish. Hunters seek an area where game can be found. Looking after the needs of people on vacation has become big business.

Wildlife also has other important values. Many types of wildlife are links in food chains from which we benefit. The fish we eat, for example, depend upon many other small aquatic animals for their food. These small aquatic animals that feed the fish are wildlife too. Also, many types of native animals are important as *biological controls.* A bird that eats an insect pest serves as a biological control. The bird reduces the pest population.

In the early days of our country's history, these facts were not so evident. Forests were cut away, even on the steeper slopes. Fish were trapped, and streams were polluted. Market hunters killed billions of game animals and birds. The passenger pigeon, for instance, was once one of the most common birds in North America. But it nested in colonies in the northern forest. The existence of these colonies made it easy for market hunters to kill millions of passenger pigeons. Today, the passenger pigeon is extinct. Other types of mammals and birds sought by the market hunters were reduced to the vanishing point.

For the most part, market hunting is a thing of the past. But we still have a great deal of unnecessary stream pollution. And we do not give enough attention to preserving natural foods and cover for wildlife.

The meaning of conservation. Today, many people are interested in ***conservation.*** It involves the wise use of resources. You use forests in such a way that new trees can grow and there will be forests and forest products for years to come. You use the soil in such a way

23–4. The passenger pigeon is now extinct because of the great numbers that were killed for food. (*John H. Gerard from National Audubon Society*)

that it will keep on producing good crops. You provide conditions so that wildlife will survive. All of the resources thus provided are for human benefit, both at the moment, and in the future.

Another area of concern relates to the appearance of our communities. We now have laws and regulations which prohibit billboards on some of the new highways. Road-side stands and unsightly groups of small shacks are also banned. So is littering and the dumping of refuse along highways and in park areas. All of this is done to preserve the natural beauty of the countryside. As a result, the entire population profits.

THE FORESTS

The forests are among the more important natural assets of the modern world. They are, of course, related to the preservation of many kinds of wildlife. But they also produce wood and wood fiber, for which there is always a heavy demand. This is why there is growing concern about the manner in which forests are maintained and used.

Throughout human history, men have turned to the forests for many materials. In former days, forest products were largely fuels and lumber. But times have changed, and modern industry fabricates thousands of useful items that have their origins in trees.

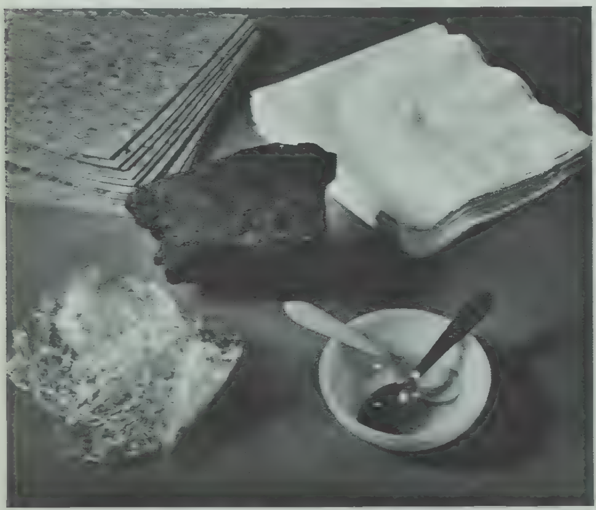
Formerly, a good many forest materials such as small limbs of trees, chips, and sawdust went into the discard. But now, many of these materials are converted into useful articles.

Forests of the world. Much of Europe and Asia was once forested, but the trees have been removed from many areas in these lands. In fact, the world's largest forest reserves now are the tropical forests of the East Indies, and Central and South America.

23–5. Trees are raised on special tree farms to insure good forest conservation and production. (*International Paper Company*)

Settlers who came to the East Coast of North America cut away the forests in many places, so that they might have fields for crop plants. But much of the hilly and rocky land that was laid bare did not prove to be well suited to crop production. With the trees gone from the hillsides, running water began to carry away the topsoil at an increased rate. When the Ohio and Mississippi Valleys were opened to settlement, many of the farmers flocked to these areas. Here they found a soil better suited to agriculture.

Many of the old farms of the eastern area were abandoned in time, and some of the lands became forested again. We still have extensive forest reserves in the United States, and we have learned to use them more wisely than once was the case. When trees are harvested, provision is made for the growth of new trees. Tree farms also have been established in many areas. It has been estimated that in the last few years more new wood growth has been produced in the United States than has been taken from the forests. This is not to say, however, that certain special types of trees have not become scarcer.



23–6. Some of the many products made from wood. (*Grant Heilman*)

Wood pulp for many purposes. When you shred up wood, you get a substance called *wood pulp,* which has many uses in modern life. Paper can be made from cotton rags, linen rags, or even the stems of crop plants. But most of our paper now comes from wood pulp.

Some wood pulp is simply made by shredding up the wood fiber. In this case, gums and other impurities remain in the product, and paper made from it is of poor quality. In other cases, however, wood pulp is treated chemically to remove the materials that are not wanted. Only ***cellulose*** (*sell*-you-lose) remains, and this is the material that forms the walls around plant cells. It is the same cellulose that makes up cotton and linen fibers. Paper made from pure cellulose is of good quality. But almost any forest tree can be used today to make some sort of paper.

Along with cotton fibers, wood pulp is used to make a number of plastics, including leather substitutes and the rayon which appears in some modern fabrics. The cellophane used to package foods and other substances also is a cellulose product.

But this is only a beginning. From wood tissues in general, we obtain acids, adhesives, alcohol, animal foods, dyes, explosives, oils, photographic film, turpentine, rosin, soil conditioners, stains, sugars, and substances employed in making linoleum, paints, and soaps.

Lumber and related products. While wood pulp has become very important, we still use much of our annual tree crop for lumber and other building materials. For the most part, this lumber comes from about 30 species of trees found in western and southern forests.

Plywood is made by building up layers of thin wood slices with strong adhesive material between them. The grain in one wood slice is at right angles to the grain in the neighboring wood slice. Then the wood "sandwich" is put in a press, in which it is heated and squeezed together as it dries. Powerful beams, made up of a number of wood sections, are now produced in a similar fashion.

INVESTIGATING PLANT AND ANIMAL FIBERS

Our clothing is commonly made of plant fibers like cotton and linen, animal fibers like silk and wool, or synthetic fibers like rayon and nylon. Each type of fiber has special properties that make it useful in preparing thread and cloth. Obtain small samples of several kinds of cloth. Select samples that contain only one kind of fiber. Pull out single threads of each sample, and untwist the thread ends so that the individual fibers are exposed. Using the low power of a microscope, examine the various fibers. Write a description of each kind of fiber in your notebook.

Test the strength of each type of thread by pulling on the ends until it breaks. Record your findings in your notebook. Burn a tiny sample of each cloth type, while holding the sample with a forceps over a glass or metal container. Note the rate at which each sample burns, the odor produced, and the kind of ash that remains. Dip a small piece of each sample in water. Place the wet samples on a paper towel, and see how long it takes each type to dry out. Summarize all of your findings in your notebook.

ANALYSIS Prepare answers to the following questions in your notebook:

1. How can each type of fiber you tested be distinguished from the others?
2. What did the plant fibers seem to have in common? The animal fibers? The synthetic fibers?
3. How might a similar study be made of types or grades of paper?

FOODS FROM SEAS, LAKES, AND STREAMS

Most of the foods men eat today come from plants and animals that are raised on farms. Wild game, and native fruits and vegetables, are still available in some areas, but food from such sources is a minor part of human fare. In the case of fish and some other sea products, however, the story is somewhat different. Sizeable quantities of seafoods are consumed every year.

Ocean fisheries. In a recent year, about 25 million tons of fish were taken from the oceans, lakes, and rivers of the world. United States fishermen caught over 4 billion pounds of fish in the Atlantic and Pacific Oceans and the Gulf of Mexico. The fish taken in largest quantity included several species of tunas and salmons, herring, and the young herring that we call sardines.

Most fish are eaten fresh today, but tunas, salmon, and sardines are often canned. And some types of fish are smoked and salted. Natural supplies of certain species, such as various salmons and codfish, are not as large as they

23–7. A salmon fishing boat loaded with its catch. (*Canned Salmon Institute*)

once were. We import both frozen and canned fish from other nations.

Fish from lakes and streams. Most of the freshwater fish sold in the United States come either from the Great Lakes or the Mississippi River system. Fish from these sources will generally total over 100 million pounds a year. This, of course, is considerably less than the fish catch from the seas. Lake trout, whitefish, and smelts are products of the Great Lakes fishery. From the rivers come catfish, buffalo fish, and carp.

The significance of freshwater fish does not end, however, with the few species we see in the markets. This is because game fish, such as various types of trout, bass, perch, and pike provide sport for anglers. During their vacations, fishermen flock to areas where fish are likely to be found. Good fishing means prosperity for people who live in such places.

Oysters and clams. Oysters once were abundant along portions of both the East Coast and the West Coast. They are mollusks, and as adults they live with their shells attached to solid objects on the ocean floor. In the first part of their life cycle, however, they are tiny, free-swimming larvae, without shells. Millions of these larvae are produced each year, but most of them are devoured by hungry enemies, while they are still very young.

Today, native supplies of oysters are very much reduced. About half of the oysters we eat come from "farms," which have been established on both the East Coast and the West Coast. Some of the farms produce the two types of native oysters. Others, on the West Coast, raise two species of oysters that have been introduced from Japan.

Various edible species of clams are also native to the Atlantic, Pacific, and Gulf Coasts. They too are mollusks, that live on the bottom of the shallow sea in some cases, or buried in the sands of tide flats in others. Included in this group are the soft clams, hard clams, and surf clams of the East Coast. Along the West Coast are species known as butter clams, little-neck clams, and razor clams.

Lobsters, crabs, and shrimp. These animals are related types that belong to

23–8. Tongs dropping oysters raked from bottom onto culling board. (*Dept. of Chesapeake Bay Affairs*)

the crustacean group. Like insects, they have hard, outer coverings composed of chitin. Their story is similar to that of the mollusks; once they were abundant, but their use as human food has taken its toll.

The American lobster is an East Coast species that has been famous since the days of early settlement. As an adult, it lives on the sea bottom, and uses its giant claws to capture any small animals that will serve as food. Lobsters of this species weigh as much as 45 pounds. Fishermen capture them in traps which are baited and sunk in shallow waters along rockbound coasts.

23–9. Youthful Maine lobsterman gets his traps and buoys ready for the spring fishing season. (*Dept. of Sea and Shore Fisheries, State House, Augusta, Maine*)

Other species of true lobsters occur along the coasts of Europe. The sea crawfish, from which we get "lobster tails," is a somewhat different animal that lacks the giant claws of true lobsters. Most of the "lobster tails" in American markets come from South Africa. Other varieties of sea crawfish, however, are found in the Pacific Ocean, and the waters around the West Indies. Freshwater crayfish, belonging to a number of species, are much smaller animals. Some of the larger crayfish are occasionally used as human food.

Edible crabs exist along many coasts. As they grow, they must, from time to time, shed their hard external skeletons. So a "soft-shelled crab" is an ordinary crab that has recently lost its outer covering. In modern times, the Alaskan king crab has become famous because of its edibility and large size. But other species exist along many of the world's coasts. Crabs are captured by using traps, nets, or baited lines.

Shrimps are relatively small crustaceans which live in shallow seas and some river mouths. They belong to a variety of species. The so-called "giant shrimp" come from fairly deep waters in the Florida and West Indian area. Shrimps are a very popular food and shrimp fishing is a big business.

23–10. Shrimp fishing in the Gulf of Mexico. (*Standard Oil Co., N.J.*)

CULTIVATED PLANTS

Many of our cultivated plants have been under man's dominion for at least 3,000 years, and some of them for much longer periods of time. Ancient tribesmen, the world over, must have been on the lookout for such plants. Certainly, most of the varieties we raise today come from species handed down to us by men who lived long ago. In recent years, we have used our knowledge of heredity and selection to develop many improved varieties of these plants, and we have added a few new species to the cultivated group.

New citrus fruits. Good examples of plant improvement are provided by the *citrus fruits.* These fruits include the oranges, grapefruits, lemons, and limes. Most of them appear to have had their homelands in southeast Asia.

23–11. Coffee is a major cultivated plant. Here coffee beans are being dried on sunlit patios. (*Pan-American Coffee Bureau*)

The Chinese were raising both sweet and sour oranges centuries ago. Hundreds of years passed before the rest of the world become seriously interested in these fruits. Then some people in southern Europe began to raise sour oranges. Sour oranges were also planted in what is now Florida. Later on sweet oranges became more popular than the sour varieties. It was found that sweet orange stems could be grafted on the rootstocks of sour orange trees.

Before many years passed, sweet oranges were being produced in the warmer parts of both North and South America. One day a Brazilian orange tree was observed to bear fruits that had no seeds in them. This was something new and desirable. The seedless condition apparently was the result of a mutation. The new fruit became known as the navel orange.

But how can you raise more navel oranges when you have no seeds to produce trees? The solution is that you graft navel orange stems on the rootstocks of ordinary young orange trees. Navel oranges are now grown extensively in Southern California.

One puzzling little problem is posed by the question, "Where did grapefruit come from?" About two centuries ago, an English ship captain is said to have brought some citrus seeds from southeastern Asia to the West Indies. At any rate, trees known as shaddocks soon began to grow in the West Indies. Shaddocks are citrus trees that bear fruits a good deal larger and coarser than grapefruits. Now after a time, grapefruit trees appeared in the same West Indian area. Had the English captain also brought grapefruit seeds from Asia? Probably not, for no wild grapefruit trees are known to exist in south-

eastern Asia. So perhaps the grapefruit trees also were the result of a mutation. The grapefruits we raise today are derived from the wild grapefruit trees of the West Indies.

Plants for many purposes. These examples will give you some idea of how new plant varieties can be developed. Scientists are constantly on the lookout for mutations that may prove useful. In addition, we protect our cultivated plants against weed competition and the attacks of insects and disease-producing parasites.

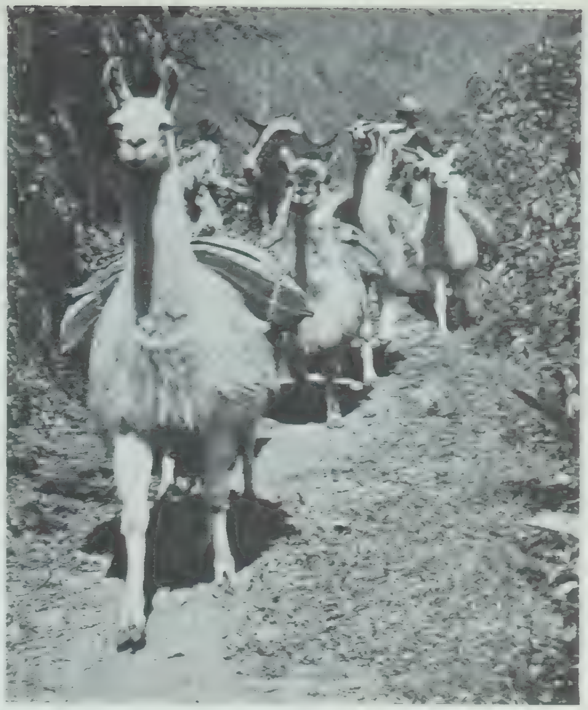
Certain crop plants are raised to provide food. We eat some of these foods ourselves, and feed others to domesticated animals. What we use depends upon the plant; it may be the roots, stems, leaves, seeds, fruits, nuts, flowers, or some combination of these parts.

Other cultivated plants are grown for a variety of purposes. Some provide beverages such as coffee and tea. Some are sources of plant fiber that is spun to make thread; then the thread is woven to produce fabric used in garments. Certain plants are sources of useful drugs, or of plant oils, and various species are raised as ornamental plants, because they have attractive flowers.

DOMESTICATED ANIMALS

Some students of history believe that man's first domesticated animal was the dog. This may well be true, for dogs might have aided primitive tribesmen in hunting, and some native tribes have used dogs for food, right down to modern times.

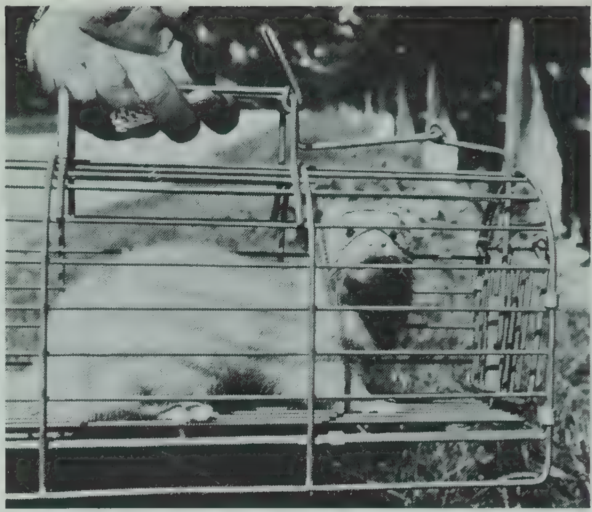
A desirable domesticated animal must first of all be useful to man. Usually this means that it must serve as a beast of burden, or be a source of food, or both. It also should be a species that will reproduce well in captivity. And it should not compete directly with man for food. For example, we can raise cattle or sheep on the forage crops that do not serve as human fare.



23–12. The llama is an important domesticated animal in Peru. (*Henricks Hodge*)

Domesticated mammals. Camels, horses, cattle, pigs, sheep, and goats have all been domesticated for a long time. Men have used some or all of them as sources of food, and for their hide and hair. Camels, horses, and cattle can be employed to pull or carry loads. In addition, milk supplies are obtained from cattle, goats, and camels in various parts of the world.

Domesticated birds. Pigeons and chickens were domesticated in the old world, at an early date. They provide food in the form of flesh and eggs. Sometimes they are sources of useful feathers. So are the ostriches that we began to raise in recent times.

23–13. The mink on the left is a natural wild mink; the mink shown on right is bred for its fur. (*Left, Karl Maslowski from Photo Researchers; right, Emba Mink Breeders Assoc.*)

The Aztecs, who lived in Mexico before the Spanish conquest, domesticated the turkey. The Spaniards transported turkeys to Europe, and later on American colonists brought the birds back across the Atlantic to our East Coast. Another American bird, the muscovy duck, is descended from a South American species. Other ducks and geese come from wild species of both the Old World and the New World.

The guinea fowl is a much more recent domestication than any of the preceding. It also differs from those previously mentioned, because it comes from Africa.

New domesticated animals. We are, without doubt, in the process of developing some new domesticated animals today. Chief among them are furbearing types including foxes, minks, and chinchillas.

It is noteworthy that several mutations have appeared among the furbearers now raised by man. These include special varieties, such as the silver fox, the cross fox, the platina fox, and the silverblu mink.

You probably would not call fish domesticated animals, but men have raised some of them for a long time. In both Asia and Europe, the practice of raising carp in ponds is longstanding. Today, rainbow trout are produced in a similar manner, both in the United States and in Europe. There is every indication that fish raising will become more common in the future. There also is a growing tendency to produce various types of game birds in captivity.

MAINTAINING BALANCED COMMUNITIES

In Block II, you learned why balanced communities are desirable. They are likely to be productive, and in them, problems of pest control are at a minimum. So our concern is to maintain communities in such a way that the balance in nature is not badly disrupted.

This is not always easy to do. Even in a balanced community, changes take place all of the time. Conditions of life are altered, and adjustments of the var-

ious populations must always be made. Mutations occur, and other adjustments must follow. So even, the balanced community is changeable, but it is also more or less stable.

Problems caused by production. The human population has increased greatly in recent times. There is every indication that this trend will continue in the future. We can no longer look to natural sources for the bulk of our food, and the many other materials used in modern life. We must depend increasingly upon the plants and animals that we raise.

This means that when man moves into the natural community he must bring with him various cultivated plants and domesticated animals. He must clear fields and plant them with crops. As a result, the balance in nature is almost certain to be disrupted, at least for the time being.

Establishing a new balance. Once man has taken his place in the natural community, the natural community can never return to its former state. New species of plants and animals have been added. Species that formerly were common have disappeared or declined in numbers. But it is entirely possible to achieve a more or less balanced economy, based upon the populations that now inhabit the area. Such a balance or near-balance in nature is one of the aims of conservation.

WORD MEANINGS

On a sheet of paper in your notebook copy the words in the first column. Write in the statement from the second column that goes best with each of these words.

1. cellulose	Materials used in making cloth.
2. cover	Species that destroys pests.
3. biological control	The wise use of natural resources.
4. conservation	All of the organisms in a community that we do not raise.
5. wildlife	Animals that are now raised on "farms."
6. fibers	Chemical substance from which paper is made.
7. oysters	A type of fruit.
8. citrus	Places where animals can find a refuge from their natural enemies.

SELF TEST

Indicate whether each of the following items is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. The plants and animals that normally live in a community make up its wildlife.
2. Cover consists of places where animals can take refuge from their enemies.
3. Most of the animal species that live in a forest are better able to survive, if the forest is destroyed.
4. Many types of wildlife are important links in food chains.
5. A biological control is a species that feeds upon our crop plants.
6. Plywood is a building material that is made from the cotton plant.
7. Many types of cloth are made from plant fibers.
8. About the only modern uses of forest products are as fuels and lumber.
9. There is more forest land in the United States today, than there was in the days of the early settlers.
10. Good quality paper is made primarily of cellulose.
11. Most of the fish that we eat today come from lakes and rivers.
12. The Great Lakes and the Mississippi River System provide our largest source of freshwater fish.
13. Native supplies of oysters have increased about as fast as man has used them.
14. True lobsters have giant claws.
15. A "soft-shelled crab" is an ordinary crab that recently shed its skeleton.
16. Most of the plants we raise today are descended from species grown many years ago.
17. Most citrus fruits are thought to have had their origin in the Americas.
18. The navel or seedless orange is the result of a cross between a sweet and a sour orange.
19. It is sometimes possible to get a twig of one kind of tree to grow on a stem of another kind.
20. Most domesticated animals compete directly with man for food.
21. Among the animals most recently domesticated are foxes and minks.
22. Even a balanced community is subject to changes as time goes on.
23. In recent years, the human population has declined, and there is indication that this trend will continue.

DISCUSSION QUESTIONS

1. How is cover related to the survival of wildlife? How is food related?
2. Why is the preservation of wildlife important? How can this be done?
3. What kinds of organisms act as biological controls?
4. What is the real meaning of the word "conservation"?
5. What is wood pulp, and why is it important?
6. What is cellulose, and how is it used?

7. In what ways has man learned to use forest resources more wisely?
8. What uses have been found for wood pulp?
9. How are ocean resources proving to be of increasing importance?
10. What is happening to the natural supplies of salmon and codfish?
11. What general uses has man found for plants, in addition to providing a food supply? Give examples of each use.
12. Why is it that some crops are grown only in certain areas of the country?
13. Of what importance are plant mutations to man?
14. In what ways do we use our domesticated animals?
15. How is the balance in nature related to pest control?
16. Why does man's presence in a community tend to disrupt the balance in nature?
17. How is it possible for man to live in a balanced community?
18. In what ways is it an advantage to maintain balanced communities?

THINGS TO DO

1. Plan and carry out a field trip to study existing types of cover in your community, as well as sources of natural food for wildlife. Note that suitable nesting sites and burrows, where young can be reared, represent one type of cover.
2. Prepare a bulletin board display to show types of animals that serve as biological controls. You can use pictures or diagrams to show what the controls are, and the types of pests that are destroyed.
3. After consulting the references on page 524, prepare a report on *predators.* Explain how they are related to the life of a community, and why their presence may actually favor various other species.
4. Using a map of the world and pictures or sketches of plant foods, prepare a bulletin board display to illustrate where various foods originated.
5. Find out what you can about the methods used to graft the twigs of one kind of plant to the stems of another kind. Show the class how grafts are made, using fresh soft twigs.
6. Find out how different varieties of plants are crossed to produce hybrid plants. Show the class how this is done, using models or actual flower buds.
7. Using reference books, write a report on the methods used to farm silkworms, trees, furbearing animals, fish, or oysters. Be sure to mention problems involved in the raising of such organisms, and how these problems are being met.
8. Today, some people believe that in the future man will have to depend more and more on the ocean as a source of food. Prepare a

list of the kinds of food now being obtained from the oceans of the world. Prepare a second list of possible sources of food from the ocean; that is, food sources that are not presently being used to any great extent.

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BLOCK IV

Laboratory Investigations

In Chapters 18–23, you studied how organisms grow and reproduce. You learned how characteristics are passed from parents to offspring and how those offspring with favorable characteristics are most likely to survive. In this section, you will find instructions for ways to observe such things as population growth, life cycles, and embryo development, in more detail. You also will find suggestions for demonstrating patterns of heredity and certain environmental influences on populations.

REPRODUCTON IN MICROORGANISMS

Some microorganisms have very simple life cycles. In a favorable environment, a single-celled form may grow to a certain size and then reproduce by splitting in half. This, of course, results in two new daughter cells, which in turn may grow and reproduce. Yeast cells have such a life cycle, but instead of splitting in half to reproduce, a daughter cell appears as a small outgrowth from the parent cell. This process is called budding and can be observed in an active yeast culture by using a microscope.

GROWTH OF A YEAST POPULATION When conditions are good, yeast cells may reproduce in a matter of minutes. Such short life cycles result in a very rapid increase of the populations. It is possible to demonstrate such growth by counting cells in small samples of a yeast culture. To do this, make a 10 percent solution of molasses or grape juice in water. Put about 10 milliliters of this medium in a test tube and add a single grain from a package of active dry yeast. Mix the yeast and culture medium by shaking the tube. Be sure to shake the tube carefully.

Place a drop of yeast culture on a clean slide. Put a cover glass over the drop, and focus on some yeast cells, using high power. Count the total number of cells that you see. Record your count on a copy of the chart shown at the top of page 526.

Age of culture (In hours)	Number of cells (per field of view)					Average
	1	2	3	4	5	

The age of the culture at this time is 0 hours. Move the slide to some other part of the drop. Make a second count. Record the count and repeat this procedure until five counts have been made. Calculate the average number of yeast cells in a high-power field of view.

Plug the culture tube with cotton and leave it in a dark place at room temperature. Each day for several days, determine the average number of yeast cells per high-power field. Be sure to shake the tube before taking a sample, as the cells will tend to settle to the bottom.

At the end of your study, prepare a line graph of your data. Use the age of the culture in hours as the units of the horizontal axis and the average number of cells per high-power field as the units of the vertical axis.

ANALYSIS Prepare answers to the following questions in your notebook:

1. Describe the population growth pattern of your yeast culture.
2. In what ways do you think yeast population growth is similar to growth of others kinds of microorganisms?
3. What do you predict would happen to the yeast population if your study had been continued for many days? Why?
4. What environmental factors probably affect microorganism population growth? Explain.

THE LIFE CYCLE OF A MOLD Molds have a life cycle somewhat more complex than that of yeast or bacteria. It is possible to observe the steps in the cycle by using the following technique.

Prepare some nutrient agar in test tubes. Plug the tubes with cotton and sterilize them. At the same time, sterilize some microscope slides inside of small, cotton plugged jars. Put a bit of paper towel inside each jar. When the jars have cooled, remove one slide at a time. Pour a very small quantity of melted nutrient agar on each slide. Use just enough agar to make a thin film covering about two-thirds of the slide. Put the slide back into its jar and replug the jar. Position the jar so that the slide is lying right side up.

Obtain some bread mold or mold from overripe fruit. Using a sterile inoculating needle, put a tiny bit of mold at one end of the agar film on a slide. Put the slide back in the jar, replug it, and leave it overnight in a dark warm place. Treat the other jars in the same manner.

Select one slide upon which mold appears. Observe what occurs daily,

using the low power of a microscope. You may be able to measure how fast it grows. To do this, measure the distance the mold spreads in 24 hours. Or use high power to focus on the end of a single thread of mold. Move the slide until the end is at the edge of the field of view. Leave the slide in place for a half hour or so. Check it every few minutes to see if the thread has moved. If the thread grows some fraction of the distance across the field in a given amount of time, you can calculate the rate of growth. The diameter of the field can be measured by looking at the millimeter marks on a plastic rule.

In time, your mold probably will form reproductive spores. These are single-celled structures that often travel in air as dust particles. In a favorable environment, spores can germinate to form new plants.

ANALYSIS In your notebook prepare answers to the following questions:

1. Describe the life cycle of the mold.
2. Assuming you exposed your slide to spores, how long did it take the mold to complete its life cycle?
3. Do you think that the time it took was related to temperature? How could you find out?
4. How fast did your mold grow in millimeters per hour? How fast have you grown in millimeters per hour from the day you were born?

REPRODUCTION IN HIGHER PLANTS

Some green plants, like mosses and ferns, produce spores that function much like those of fungi. That is, single-celled spores are released from parent plants. In favorable surroundings, they germinate and continue the life cycle.

Cone-bearing and flowering plants produce seeds. Each seed serves as a container for a tiny undeveloped embryo. In this form, the embryo plants can be transported some distance from the parent. When conditions are satisfactory, an embryo may begin to grow, and we say that the seed is sprouting.

TESTING SEEDS Before a biologist uses a particular group of seeds in an experiment, he needs to know what percentage of the seeds will probably sprout. A farmer needs the same information before he takes the trouble to plant a crop. The test is a simple one. To demonstrate it, select some seeds to examine. Put 50 to 100 of them on a moist paper towel in a pan and cover them with a second piece of moist towel. Keep the seeds in a dark, warm place for a couple of days. Be sure to keep the towels moist. It may be necessary to cover the pan to reduce evaporation. Count the seeds that sprout and calculate the percentage. This can be done using the formula:

$$\frac{\text{number sprouting}}{\text{number tested}} \times 100 = \text{percent sprouted}$$

ANALYSIS In your notebook prepare answers to the following questions:

1. What percentage of your seeds sprouted?
2. If you used ten of these seeds in an experiment, how many of them could you expect to grow? If you used only five? Two?

3. What is the danger of using only one or two seeds in an experiment, even when the sprouting percentage is known to be high?

INVESTIGATING THE EFFECT OF SOAKING ON SEEDS As you know, seeds are usually quite dry, and they must be moist before they will sprout. Do you think soaking seeds in water will promote more rapid sprouting? To find out, obtain some seeds known to have a high sprouting percentage. Soak at least ten seeds in jars of water for each of the following times:

Group 1.	72 hours
Group 2.	48 hours
Group 3.	24 hours
Group 4.	4 hours
Group 5.	2 hours
Group 6.	1 hour
Group 7.	0 hours

It is important that all the soaking be completed at the same time. To do this, decide when to start the sprouting test. Begin soaking the first group of seeds 72 hours before the test, the second group 48 hours before, and so forth.

After soaking the seeds, remove them from the water and put them in separate pans on moist paper toweling. Be sure to label the pans so you can tell them apart. Observe the seeds each day and record the number of seeds that have sprouted in each group.

ANALYSIS In your notebook prepare answers to the following questions:

1. Did soaking seem to promote sprouting in the seeds tested? Explain.
2. If it does promote sprouting, what amount of soaking seemed to be most effective? Least effective?
3. Do you think seeds can be watered too much? What evidence do you have?
4. Do you think that what you have learned about the effects of soaking can be applied to other kinds of seeds? How could you find out?

SEED PARTS AND SPROUTING How much of a seed must be present before it will sprout? Is the seed coat essential? The seed leaves? To find out, soak 25 lima bean seeds in water overnight. Divide the seeds into five groups of five seeds each. Treat the groups as follows:

Group 1. Plant the seeds just beneath the surface in some loose moist soil or vermiculite.

Group 2. Remove the seed coats and plant the seeds as before.

Group 3. Remove the seed coats and one seed leaf. Be careful not to damage the plant embryo. Plant the seed leaves that have the embryos still attached.

Group 4. Remove the seed coats and one seed leaf. Cut the remaining seed leaf so that the plant embryo is attached to a small piece of one seed leaf. Plant these.

Group 5. Carefully remove all the seed leaves and plant the embryos.

Keep the planters covered with some moist paper towels. Observe the planters each day for several days to see if any of the parts are sprouting. Record your observations.

ANALYSIS In your notebook prepare answers to the following questions:

1. What parts of the lima bean seem to be essential for sprouting? Explain.

2. What parts of the lima bean seem to be dispensable? How so?
3. Why was the first group of seeds included in this study?
4. What natural environmental factors might act to remove seed parts?

REGENERATION IN PLANTS AND ANIMALS

Many organisms have considerable ability to restore lost parts. For example, if the branches are cut from a tree, new branches may soon appear. A stem cut from a geranium plant may form roots, if left in water or planted in moist soil. Under certain conditions, a leaf may grow roots and stems and develop into a complete plant. This provides a way for some plants to reproduce themselves from parts that drop off or are cut away. Such offspring are said to be produced asexually.

Many animals also have the ability to replace a lost body part. A lizard may drop its tail, if this part is held by a predator. In time, a new tail grows and replaces the lost one. A crab may drop a leg that is caught in a crevice between rocks and then grow a new leg. A piece of starfish may grow into a complete starfish by replacing all the missing structures. This ability of plants and animals to replace lost parts is called regeneration.

REGENERATION IN A FLATWORM The flatworm, *Planaria dorotocephala*, will sometimes reproduce by constricting itself in the middle and separating into two halves. Each half then regenerates the missing parts. That is, the tail section grows a new head and the head section grows a new tail.

Since planarians are fairly widespread in freshwater streams and ponds, it may be possible for you to investigate regeneration, at first hand. Look for flatworms on the undersides of rocks or pieces of debris, in slow moving water. They may look like tiny blobs of jelly. You can transfer them to a jar of pond water with a cotton swab, or by picking them up gently with your finger. Another method for collecting these animals is to place a bit of raw meat, such as beef or liver, at the edge of a stream or pond. Any planarians that attach to the meat can be shaken off into a collecting jar. Or you can purchase planarians from a biological supply house. You should know, however, that some species of planarians have better ability to regenerate than others do.

Put your worms in a shallow pan of pond water. Keep the pan covered or in a dark place. The temperature should be at about 50°F. Every few days place a small bit of raw liver in the water, and let the worms feed for an hour or two. Remove the liver and replace the water with fresh pond water. Be sure that no particles of liver remain as they will decay and cause the worms to die.

To observe regeneration, place a worm in a drop of water in a petri dish or on a glass plate. If the worm is active, slow it down by putting the dish on some ice or in a refrigerator for a few minutes.

Using a sharp razor blade, cut the worm across the middle. Repeat this procedure on two or three worms. Put the head ends in one petri dish of pond

water and the tail sections in another. Keep the dishes covered or in a dark place. Observe the sections each day, using a low power magnifying glass. Pay particular attention to the end that was cut. Make sketches and measurements of the parts each time. Record your observations.

ANALYSIS Prepare answers for each of the following questions in your notebook:

1. Describe the way in which a planarian regenerates lost parts.
2. Do the regenerated parts appear normal? How so?
3. Which sections seemed to have the greater ability to regenerate, the heads or tails? Explain.
4. How small a piece of worm do you think can regenerate all the lost parts? Describe an experiment that would help answer this question.
5. Does man seem to have any ability to regenerate? How so?

EMBRYO DEVELOPMENT

Some lower animals, like the hydras and certain flatworms, have the ability to reproduce asexually. However, most higher forms produce offspring by sexual means only; that is, by the union of egg and sperm cells. The result of such a fusion of sex cells is a fertilized egg. Under favorable conditions a fertilized egg cell will undergo division and begin developing into an offspring. The developing offspring is called an embryo.

DEVELOPMENT OF AN AMPHIBIAN EMBRYO If you can find some freshly laid frog or toad eggs, it is possible to raise them in the classroom. By observing the eggs daily you can gain some first-hand knowledge of how they develop into tadpoles.

Although the egg laying time varies with each kind of amphibian, many species breed in the spring. Some kinds lay eggs as soon as the winter ice disappears, while others do not breed until May or June. In any event, if you find some egg masses or jellylike strings of toad eggs, keep them in shallow aquaria or in stacking dishes under a few inches of pond water. Add a few aquarium plants to help provide oxygen. Do not put too many eggs in any one container. Thirty to 40 will be enough.

Unfertilized eggs should be removed. They look light or cream colored on top. Fertile eggs have their black surfaces up. With scissors, cut the unfertilized ones free from the mass and discard them. Put one or two fertile eggs in a small vial or test tube of pond water. Plug the tube with cotton to slow evaporation. This way you can study the development at close range. Each day use a hand lens or dissecting microscope to observe changes. Record your observations. Include sketches of what you see. Be sure to keep the tubes cool. When you are not actually observing the eggs, leave the tubes standing in an aquarium partially filled with water. This will keep the eggs and the water from warming up too fast.

Do you think temperature affects the rate of amphibian egg development? Plan an experiment to test your idea. Have your teacher check your plan before you carry it out.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. How would you describe the changes that take place in an amphibian egg as it develops?
2. Did all the eggs hatch at about the same time? Explain.
3. Does temperature affect the rate of development? What evidence do you have?
4. What other environmental factors probably affect amphibian egg development? How could you test your ideas?

DEVELOPMENT OF A CHICK EMBRYO If you can obtain some fertile, but unincubated hen's eggs, it may be possible for you to study chick embryo development. Put the eggs in an incubator and follow the directions that came with it. If an incubator is not available, construct one from a wooden box. To do this, cover the inside walls with heavy cardboard so there are no cracks in them. Also cover the top of the box with wood or cardboard. Install an electric light bulb at one end to serve as a heater. With the box closed, leave the light on for several hours. Using a thermometer, determine a point, probably some distance from the light, where the temperature is 103°F. If the temperature in the box is too high, use a smaller light bulb. If the temperature is too low, use a larger bulb.

Once the 103°F distance is known, place a dish of fertile eggs at this position. Also put a dish of water in the box near the light to keep the eggs from drying out. Check the temperature from time to time to see that it remains at 103°F. Make adjustments whenever necessary. Every 12 hours, turn each egg over. A pencil mark on the shells will help you tell which way to turn them.

At the end of 24 hours, remove an egg. Put it in a bowl padded with paper towel. Let the egg stand for a few minutes to allow the embryo to float to the top, then puncture the shell with the tip of a fine-pointed scissors. Using just the tips of the scissors, cut off the top of the shell. With a low power magnifier, observe the embryo. Make sketches of what you see.

Repeat this procedure each day for at least five days. In your notebook, describe any changes that you notice.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. What parts of the embryo develop first? What parts develop next?
2. As the embryo developed, what seemed to be happening to the egg yolk? Explain.
3. What was in the egg besides the embryo and yolk? What is the function of these parts? How do you know?
4. In what ways do you think the environment affects chick embryo development? How could you check your answer?

DOMINANT AND RECESSIVE GENES

You have learned that some genetic units or genes are dominant over recessive genes. Every organism can be thought of as having at least two genes

for a given trait. As a result, three kinds of individuals can be identified. They are those that are pure dominant, those that are pure recessive, and those that have a dominant and a recessive gene for the traits. The individuals in the last group are called hybrids. You can illustrate these genetic combinations by using pieces of cellophane.

A CELLOPHANE MODEL Use a piece of clear cellophane to represent a recessive gene and a piece of red cellophane to represent a dominant. Sandwich two pieces of clear cellophane together. This will represent a pure recessive individual. Two pieces of red cellophane will represent a pure dominant. A piece of clear cellophane sandwiched together with a piece of red cellophane will represent a hybrid. Hold each of these combinations up to the light. It is obvious that the red cellophane is "dominant" to the clear in the case of the hybrid.

Now make similar observations using two different colors. Let two pieces of yellow cellophane represent an individual pure for one trait and two pieces of blue represent an individual pure for the contrasting trait. A hybrid will be represented by a piece of yellow and a piece of blue cellophane.

If you hold these three combinations up to the light, how many different colors will you see? This situation illustrates a genetic pattern called incomplete dominance. In this case, neither gene is dominant over the other. Instead, they seem to blend.

ANALYSIS Prepare answers to each question in your notebook:

1. In what way is red cellophane "dominant"?
2. How can yellow and blue cellophane be used to illustrate incomplete dominance?
3. As far as cellophane models are concerned, is it easier to distinguish the hybrid in the case of simple dominance or incomplete dominance? Does this hold true in organisms? Explain.

USING BEANS TO PREDICT GENETIC PROPORTIONS IN OFFSPRING You can learn a number of things about genetics by using a sack of beans. For example, let a number of beans represent the sex cells of an individual. The color of the beans can represent genes for certain genetic traits. Thus, if an individual is pure for a trait, all the beans would be the same color. If the individual is hybrid for the trait, half of the beans would be one color and half another color.

Using this idea, prepare a model of two individuals. A sack of 25 red colored beans will represent a parent pure for a dominant trait. A sack of 25 plain colored beans will represent a parent pure for the recessive form of the trait. A bean selected from each of the two sacks will represent an offspring. It is obvious that every offspring will be represented by one plain and one red bean. Also, every offspring would be a hybrid and would show the dominant trait.

But what about the offspring from two hybrid parents? To make this model, place equal numbers of plain and red beans in each of two sacks. Make sure the two kinds of beans are

nearly the same size and cannot be distinguished by touch. An offspring is represented by two beans, one from each sack. What kinds of offspring and in what proportions can be expected from these hybrid parents?

To find out, select one bean from each sack without looking. If the beans are both red, record the offspring as pure dominant. If the beans are both plain, record the offspring as pure recessive. If you select a plain and a red bean, record a hybrid. Be sure to return each bean to the sack it came from before selecting others. This will keep the numbers and proportions of beans in each sack the same.

A copy of the following chart will help you organize your data.

	Number of Offspring	Percentage of total
Pure dominant Hybrid Pure recessive		

Select beans, one from each sack, until you have recorded a total of 100 offspring. Calculate the percentage of the total each group represents.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. What percentage of the offspring in this model were pure dominant? Pure recessive? Hybrids?
2. On the basis of this study, what could you predict about the characteristics of offspring from parents hybrid for a trait?
3. How could the same type of model be used to predict the proportions of offspring from a parent pure for a trait and one hybrid for that trait? Two parents pure for the same trait?

INVESTIGATING ALBINO CORN No doubt, you are aware that certain animals are unable to produce color in their skin, hair, or eyes. The common white mouse, white rat, and white rabbit are examples. We call such animals albinos. Albinism is very often due to a recessive gene. This trait also occurs in certain plants. Such plants cannot produce chlorophyll, and as a result, they are white or yellow instead of the normal green.

It is possible to purchase a mixture of normal and albino corn or tobacco seeds from biological supply houses. If you can obtain such a mixture, carry out the following interesting investigation.

Observe the seeds carefully to see if they show variation in color. Record your observations. Separate the seeds at random into four groups. Plant each group in a separate container of moist soil or vermiculite. Label the planters and leave the first two in a well lighted place. Put the other planters in a dark place or cover them so light cannot reach the seedlings.

Observe the planters each day and when the seedlings begin to grow, record the number of normal and albino plants in each. A copy of the chart, at the top of page 534, will help you organize your data.

Planter number	Normal Seedlings	Albino Seedlings
One (light) Two (light) Three (dark) Four (dark)		

After a few days, when the seedlings are well established, treat the planters as follows:

Planter 1. Leave in a well lighted place

Planter 2. Move from the light to the dark

Planter 3. Move from the dark to the light

Planter 4. Leave in the dark

Continue to observe the plants each day for several days. Record any changes. At the end of this time, count the normal and albino plants in each planter and record the data in a copy of the following chart.

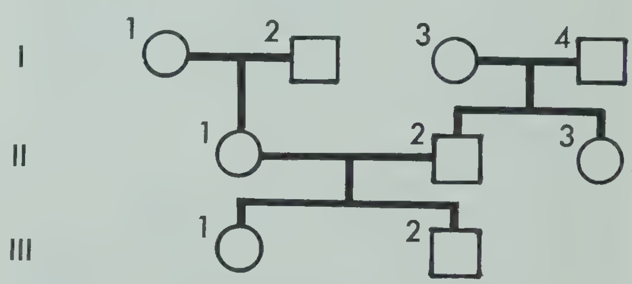
Planter number	Normal Seedlings	Albino Seedlings
One (light) Two (dark) Three (light) Four (dark)		

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. What was the percentage of albino seeds in the original mixture? How do you know?
2. What happened to the normal seedlings grown first in the dark and then in the light? How do you explain this observation?
3. What happened to the normal seedlings grown first in the light and then in the dark? Explain.
4. In what way did the environment modify the hereditary characteristics of the normal plants? Of the albino plants?
5. What would you predict would happen to the albino plants left in the light for some time? In the dark? Why?

STUDY OF A HUMAN PEDIGREE A pedigree is a chart showing something about an individual's ancestry. In many cases, studies of human pedigrees have helped biologists discover how genetic traits are passed from parents to offspring.

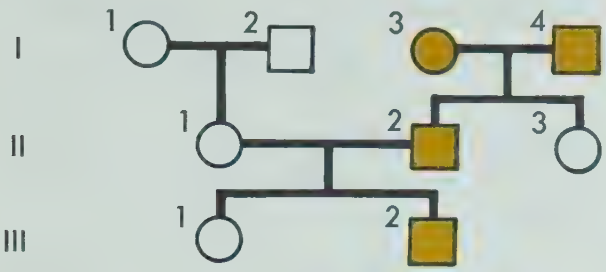
The following is a pedigree of a family:



The circles represent females, and the squares represent males. A line between a circle and a square indicates a marriage, and the line down leads to the symbols of the offspring. Each generation is numbered with a roman numeral. Each individual is numbered also. Thus, individual II-1 is the daughter of I-1 and I-2. Individual III-2 is the grandson of I-1 and I-2, and so forth.

To show how a given trait is passed from generation to generation, the symbols of those members with the trait are darkened. For example, if we wanted

to study the trait "dark eyes" we would darken the symbols of those individuals who have brown or black eyes. Using the pedigree above, we find the following:



What, if anything, can be learned from such a study? Is there any evidence that dark eyes is a dominant or a recessive trait? Dark eyes do not appear in individuals I-1 and I-2 or in their daughter, so these members do not tell us much. But consider individuals I-3 and I-4 and their children, II-2 and II-3. Both parents have dark eyes. Their son has dark eyes, but their daughter has light eyes. Which trait, light or dark eyes, is hidden in the parents? Since the dark-eyed parents produced a light-eyed daughter, they must have carried a hidden gene for light eyes. Otherwise they could not have passed it on to an offspring.

When a trait is hidden in the parents in this manner, we call it recessive. Dark eyes would be called dominant to light eyes in this pedigree.

See if you can find out something about a trait in your family or the family of a friend. To do this, prepare a pedigree of as many members as possible. Select a trait to study and darken the symbols of all those who have it. If you cannot get data for a certain member, put a question mark in the symbol.

Any of the following traits may make interesting studies:

- presence or absence of freckles
- dark or light hair
- straight or wavy hair
- free or attached ear lobes
- hair or no hair on the middle finger joint
- tallness or shortness
- ability or lack of ability to roll the tongue

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. How many individuals are represented in your study? How many generations? What percentage of the individuals have the trait you selected to study?
2. Do you have any evidence to indicate whether the trait is dominant or recessive? If so, what evidence?
3. How can such information be used to predict whether or not a given trait will appear in future offspring?

COMPETITION AMONG ORGANISMS

You have learned that organisms often compete with one another for resources available in limited amounts. For example, man and insects compete for the food provided by crop plants. Various kinds of decay microorganisms may compete for the food material in the wood of a fallen tree. And the trees of a forest may compete for the sunlight available in a limited area.

Do you suppose that competition exists among different kinds of plants growing in a garden? The following

activity is planned to help you answer this question.

COMPETITION BETWEEN PLANTS OF DIFFERENT SPECIES Obtain some seeds from two kinds of plants that you would like to investigate. You might want to use different species of garden vegetable seeds, flower seeds, weed seeds, or some combination of these. You also will need three planting boxes or flats. Fill the flats with soil. Moisten the soil, and let it stand overnight. Prepare furrows in the soil about three-fourths of an inch deep and about two inches apart. Plant individual seeds in the furrows about one-half inch apart and cover them with loose soil.

In the first flat, plant only one kind of seed. In the second, plant only the second kind of seed. Plant the third flat with both kinds, alternating them. That is, plant a seed of one kind, then a seed of the other kind, then the first again, and so forth. Label the flats, so you can remember which kind of seeds are planted in each. Keep the soil moist, but not muddy. You may want to cover the flats with glass or thin plastic sheeting until the seeds have sprouted. This will prevent rapid drying.

Be sure the flats receive nearly equal amounts of water and are equally lighted. If they are kept indoors, it may be necessary to turn them each day to prevent the plants from bending toward the windows.

Observe the plants carefully every few days. Watch for differences in appearance, color, and growth rates. Record your observations in your notebook. After the plants have grown for several weeks, you may want to compare the weights of plants grown separately with those grown together. To do this, cut ten plants close to the soil from one flat, and weigh them together. Remove ten of the same kind of plants from the mixed flat and weigh them. Repeat this procedure for the other kind of plant. Record your findings.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. Did you find any evidence of competition between plants? Explain.
2. If this experiment was carried out in a different sort of climate, do you think the results would be the same? Why?
3. For what environmental factors might plants compete?
4. Do you think the plants in the unmixed flats were competing? What evidence do you have?

COMPETITION BETWEEN PLANTS OF THE SAME SPECIES What effect does crowding have on plants of the same species? Perhaps you can find out by planting different numbers of seeds in small containers. Small jars or flower pots filled with moist soil can serve as planters. Plant 10 corn or bean seeds in the first, 20 in the second, 30 in the third, and so forth. The seeds in your last planter should be crowded closely together. Keep the planters in similar conditions of light and heat. Add just enough water to keep the first planter moist. Give the other planters an equal amount of water but no more.

When the seedlings are well established, remove 10 plants from each planter, and weigh each group sepa-

rately. Record the group weights in your notebook.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. What effect did crowding seem to have on the plants?
2. Did any of the plants seem to grow faster than others? Taller? Do you think such differences are due to environmental factors or to heredity? Why?
3. Which group of seedlings served as a control in this experiment?

TEMPERATURE AND POPULATION GROWTH

When any necessary resource is in short supply, we can expect to see this reflected in the populations of organisms. If there is little water in an area, we expect to find a small number of plants. When there are few plants to serve as food, only a small number of animals can survive. Lack of certain soil minerals may result in limited plant populations, or lack of oxygen in pond water may limit animal populations. Such factors that tend to slow down the growth of organisms are called *limiting factors.*

Do you think heat in an environment will act as a limiting factor? Some students were interested in investigating this possibility and decided to study the effect of temperature on population growth in yeast cells. Using reference books, they found that yeast cells could be grown in a culture medium of water and glucose. They also learned of a way to estimate the number of cells in a milliliter of solution. To do this, they removed a very tiny, but known, volume, and using a microscope, they were able to count the cells in that volume. From this information they could calculate the number of cells in any larger volume. This method was, of course, based on the assumption that the yeast cells were evenly distributed throughout the medium.

The students set up a series of culture tubes and filled them with culture medium, to which they had added a tiny bit of dry active yeast. They mixed the cells into the medium and removed samples for counting. The counts were recorded. Then half of the tubes were placed in a refrigerator. The others went into a dark cupboard. The refrigerator temperature was known to remain at about 12°C; while the room was controlled at 22°C. Each day, at about the same time, the tubes were shaken and counts were made of the yeast cells. The counts were recorded and averaged. The following chart summarizes the class findings:

Cultures at 12°C

Age of culture (in hours)	Number of cells (per ml)
0	50,000
24	170,000
48	300,000
72	1,000,000
96	3,250,000

Cultures at 22°C

Age of culture (in hours)	Number of cells (per ml)
0	50,000
24	2,500,000
48	7,500,000
72	17,000,000
96	40,000,000

Prepare a line graph of this data. Use age of the culture in hours as the units of the horizontal axis and number of cells per milliliter as units of the vertical axis. Plot the 12°C data with one color and the 22°C data with another.

ANALYSIS Prepare answers to each of the following questions in your notebook:

1. In what way does temperature seem to affect yeast cell population growth?
2. What sources of error in the procedure might have affected the results? How so?
3. Do you think temperature affects population growth in other organisms? What evidence do you have?
4. Do you think the population growth pattern illustrated by the 22°C data is a "typical" one for yeast cells? Why?

SOIL WATER AND PLANTS

Certain plants are adapted to live on dry soil, while others exist only where moisture is plentiful. Members of the cactus family represent a group that does well in dry areas. At the other extreme are the aquatic plants, like water lilies and *Elodea,* that live in ponds and streams.

Many garden plants grow best where moisture conditions are somewhere between the extremes. No doubt, each of these plants is well fitted to the particular environment in which it grows best, but in what ways? Are plants that live on dry soils able to exist because they have less need for water than aquatic plants? Do desert plants have less water content than garden or aquatic plants? How could you find out?

SOIL MOISTURE AND PLANT WATER CONTENT Obtain samples of plants that grow well in each of the three areas described above. Using the method described on page 273 of this book, determine the percentage water in corresponding parts of each sample. Record your findings in a copy of the chart at the bottom of this page.

Before weighing a sample of an aquatic plant, be sure to blot the outside, as dry as possible, using paper towels. You need to get rid of water that is on the outside of the plant tissue. Also, before heating the cactus you should cut the sample into small pieces. This will speed the drying process.

ANALYSIS Prepare an answer to each of the following questions in your notebook:

1. Does there seem to be any relationship between the percentage of wa-

Plant type	Fresh Weight	Dry Weight	Water Lost	Percent Water
Dry area Moist area Aquatic				

ter in plant tissues and soil moisture? Explain.

2. How do your results compare with those of other students?

3. Do you think your findings hold true for other kinds of plants that grow in such areas? How sure are you?

SUMMARY: BLOCK IV

Cell division provides new cells for growth, and for the repair of existing structures. It is the basic process in the production of offspring. Some organisms reproduce asexually, but many species of plants and animals reproduce sexually. Each parent contributes a single cell—a sperm cell or an egg cell—to the new individual.

Chromosomes contain many small units called genes. Genes contain *DNA* molecules which determine what the heredity will be. In the cells of adult organisms, chromosomes and their genes are in pairs: one chromosome of each pair comes from the male parent, and the other from the female parent. Chromosome number is the same for members of a given species.

Mitosis is a special type of cell division. In mitosis, the chromosome material is duplicated and then divided equally between two daughter cells. Mitosis takes place when a human cell divides to produce new cells for growth or repair. It also occurs when a fertilized egg cell divides again and again to produce an embryo.

Both male and female sex cells have their chromosome numbers reduced by one-half, while they are becoming mature. This reduction occurs during the process of meiosis. Then a mature sperm cell fertilizes a mature egg cell. The result is a fertilized egg cell that can develop into a new individual.

Many species of organisms produce vast numbers of spores, seeds, and eggs. If all of them gave rise to new individuals, the world would soon be overpopulated. This does not happen because the death rate in nature is very high during early life.

Various kinds of plants reproduce by cell division, spores, growth from parts, or seeds. All of the seed plants bear flowers, but flower structures vary greatly. Many flowers are incomplete. A pollen grain on a stigma forms a pollen tube, which grows down through a pistil to reach an ovary. Then a sperm nucleus unites with the egg cell. The fertilized

egg cell now begins to divide, and forms a plant embryo that is enclosed in a seed. Fleshy or dry fruits are sometimes developed around the seeds.

A good many seed plants can grow from parts. Thus, a potato plant can develop from a piece of a potato tuber. Various other plants can be reproduced from pieces of roots, from runners, or from stems. This growth from parts is an asexual type of reproduction; growth from seeds represents sexual reproduction.

Some animals reproduce asexually, some reproduce sexually, and some employ both methods. Even some of the simple animals develop special sex cells. In some cases, one individual produces both male and female sex cells. Eggs which contain fertilized egg cells are produced by many of the lower animals, such as the worms, mollusks, and insects.

In vertebrates, the sexes are generally separate. Most fishes, amphibians, and reptiles are egg layers, but some females in all three groups bear their young. This means that the eggs have developed and hatched within the bodies of the females.

Birds reproduce by means of eggs, and so do three primitive species of mammals. Most female mammals, however, bear their young. All female mammals produce milk for the nourishment of their offspring.

The *DNA*, in the genes of a fertilized egg cell, determines the course that development will take. In the more complex animals, a young embryo first develops three basic cell layers: the ectoderm, the mesoderm, and the endoderm. The adult structures are formed from cells of these basic layers. The same structures come from a given layer in all animals.

In the early days of civilization, men used a process of mass selection to develop better varieties of plants and animals. The members of any species differ from one another, and it is possible to select the "best" plants and animals as breeding stock. But mass selection is sometimes slow to produce the desired results.

Two general types of variations appear among plants and animals. Acquired characters are changes in body cells due to the effects of environment. Mutations may also be caused by the effects of environment, but they are due to changes in sex cells. Mutations can be inherited; acquired characters cannot.

About a century ago, an Austrian monk named Gregor Mendel discovered a law of heredity, while he was experimenting with garden peas. He found that certain characters are dominant over opposed characters. Thus, in his pea plants, tallness was dominant over shortness. Today, we use Mendelian selection to produce desired varieties of plants and animals. It is a faster and more certain process than mass selection.

From the fossil record, we know that the earth is very old, and that millions of years ago only simple forms of life existed. Then came periods in which dominant animal forms were successively the inverte-

brates, the fishes, the amphibians, the reptiles, and the mammals. Land plants became abundant during the Age of Amphibians, and flowering plants arose during the Age of Reptiles.

There have been many theories that attempt to explain the changes that take place in plant and animal populations. One of them is the theory of natural selection. This theory is based upon the following points:

1. More spores, seeds, and eggs are produced than can possibly develop into adults.
2. The members of all species vary, and some members are more fit than others. What makes them fit depends upon the existing conditions.
3. A struggle for existence takes place, and the fittest tend to survive.
4. Hereditary characters that have proved useful in survival are passed on to future generations. The general effect is to keep species well adapted to a changing environment.

Mutations provide new variations that enable species to change. Mutations occur by chance, rather than in response to a possible need.

The present world distribution of plants and animals depends upon the place of origin, the extent to which a species has been dispersed, and the ability of the species to survive in new and often different communities. Species vary in the extent to which they are adaptive. Some can survive only under rather special conditions of life.

Man lives in many natural communities. In these communities, his acts bring about changes in the environment, which in turn influence the trends taken by natural selection. Wildlife may be seriously affected by human acts that change the nature of fitness. Wildlife is of value to us because many species are necessary parts of food chains, other species act as biological controls, and many species add attractiveness to our vacationlands.

Conservation is concerned with the wise use of natural resources. Among these resources are the forests. From the forests we get lumber, and wood pulp that is used in making paper, plastics, and many other things we use in everyday life. We also continue to get fairly large food supplies from the seas, and from some lakes and rivers.

Since the human population has become so large, however, we must now depend largely upon the plants and animals that we raise. Many of these organisms were known to our remote ancestors. Today, we improve them by taking advantage of chance mutations and our knowledge of artificial selection. We also protect them against competition and the attacks of parasitic enemies.

Maintaining balanced communities is a problem and a challenge. After man has brought in his cultivated plants and domesticated animals, old balances can no longer exist. But it is possible to establish new balances and to do this is very much to our advantage.

WORD MEANINGS

On a sheet of paper in your notebook, copy the words in the first column of part *A*. Write in the statement from the second column that goes best with each of the words. Do part *B* in the same way.

A

1. albino
2. budding
3. hybrid
4. limiting factor
5. moss
6. recessive
7. sediment
8. seed

Organism lacking the ability to produce certain pigments.
Green plant that produces spores.
Solid material carried in river water.
Process by which offspring appear as an outgrowth from the parent.
Individual with a dominant and a recessive gene for a trait.
Condition tending to slow down the population increase of organisms.
Trait appearing in an offspring, but hidden in its parents.
Container for an embryo plant.

B

1. competition
2. cone-bearer
3. fungus
4. incomplete dominance
5. incubator
6. pedigree
7. regeneration

Chart of an individual's ancestry.
Apparatus used to keep fertile eggs at a proper temperature.
Nongreen plant that produces spores.
Condition in which neither gene of a pair is dominant over the other.
Process of replacing lost parts.
Struggle between organisms for resources available in limited amounts.
A seed producing plant.

SELF TEST

Indicate whether each of the following statements is true or false by writing the word *true* or *false* in your notebook next to the number of the statement. State briefly how you would reword each false statement to make it true.

1. Yeast cells reproduce by budding.
2. When conditions are favorable, certain microorganisms may grow and reproduce in a matter of minutes.
3. Molds have a life cycle somewhat simpler than yeasts.
4. Spores sometimes travel in air as dust particles.
5. Mosses and ferns are seed producing plants.
6. A spore is a many-celled structure.
7. A new plant, growing from a single leaf, is an example of sexual reproduction.
8. Lizards can regenerate lost parts, but crabs and starfish cannot.
9. Flatworms sometimes reproduce by constricting themselves in the middle and separating into two halves.
10. A fertilized egg results from the union of an egg and sperm cell.
11. The term embryo applies only to developing animals.
12. Amphibians most commonly breed in the winter.
13. Fertile frog eggs are black on top, while infertile ones are light or cream colored.
14. Water is put in an incubator with fertile hen's eggs to keep the temperature below 100°F.
15. A hybrid has two dominant genes for a given trait.
16. When using beans to predict genetic proportions, each bean represents a sex cell.
17. The color of the bean can be used to represent a gene.
18. Yellow cellophane is "dominant" over blue.
19. Albino plants produce more food than normal plants.
20. A parent with dark eyes may carry a recessive gene for light eyes.
21. Lack of oxygen in a pond may be a limiting factor.
22. Yeast cells reproduce more rapidly at 12°C than at 22°C.

DISCUSSION QUESTIONS

1. Describe the life cycles of a yeast and a mold.
2. Why is it important to sterilize the medium before attempting to grow microorganisms?
3. In what ways do spores aid certain kinds of organisms to survive?
4. How is a seed more complex than a spore?
5. What is the value of knowing the percentage of seeds that will sprout?
6. Distinguish between asexual and sexual reproduction.
7. How does regeneration aid in survival?
8. What is a fertile egg cell?

9. How does an amphibian embryo obtain food and oxygen? A chick embryo?
10. In order to incubate hen's eggs, the temperature must be kept at 103°F. How is this temperature maintained under natural conditions?
11. Distinguish between dominant and recessive genes.
12. In the case of incomplete dominance, how can the hybrid be identified?
13. How can the hybrid be identified in the case of simple dominance?
14. In what way is albinism a much more serious condition in plants than in animals?
15. How do you suppose seeds that will produce albino plants are obtained?
16. How is chlorophyll production related to the environment? How is it related to heredity?
17. Explain how pedigrees may be used to determine whether a trait is due to a dominant or a recessive gene.
18. In what ways do plants compete with other plants?
19. How do animals compete with one another?
20. What factors limit growth in a desert community? At the North Pole? In the deep sea?
21. In what way is a human population growth pattern similar to that of yeast cells? How is it different?

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GLOSSARY

Abdomen (*ab*-doh-m'n). A region of the body lying below the diaphragm in various animals.

Acne (*ack*-nee). A skin condition caused by an abundance of blackheads.

Acquired character. Any changes of somatic cells brought about by things and forces of the environment.

Adapted (uh-*dap*-tud). Adjusted to the conditions of life.

Adrenal (ad-*ree*-n'l) **glands.** In man, ductless glands located at the upper ends of the kidneys.

Adrenalin (ad-*ren*-uh-lin). Hormone secreted by the central portion of an adrenal gland.

Aerobic (air-*oh*-bik). Refers to organisms that use oxygen to break down food molecules.

Air sacs. Special structures attached to the respiratory systems of birds. Thin-walled divisions of the lungs in man.

Albinism (*al*-bun-*izm*). A condition in which normal pigment is lacking.

Algae (*al*-jee). Several groups of simple plants that are all food makers.

Allergy (*aller*-gie). A tendency to react unfavorably to the presence of a certain protein compound.

Amino acids. Molecules which become bonded together to form larger protein molecules.

Amphibian (am-*fib*-ee-un). A cold-blooded vertebrate, such as a frog, toad, or salamander, which does not have scales or plates.

Amylase (*ami*-lase). A carbohydrate-splitting enzyme secreted by glands of the human pancreas.

Anaerobic (*an*-uh-*roh*-bik). Anaerobic organisms only live well in an environment where there is little or no oxygen.

Anemia (uh-*nee*-mee-uh). A condition in which the hemoglobin in the blood is insufficient.

Annual (*an*-you-ul). A plant that completes its life cycle in a single growing season.

Antennae (an-*tenn*-ee). Sensory processes developed by insects and some other animals.

Anther (*ann*-thur). Structure at the upper end of a stamen in a flower.

Antibiotic (*anta*-bi-*ot*-ik). Drug extracted from a mold or bacterium that can be used to combat germs.

Antibodies (*antuh*-bodies). Chemical substances in blood plasma which destroy germs or neutralize poisonous substances produced by germs.

Antiseptic (*an*-tuh-*sep*-tik). Compound that kills germs but is too toxic to be used except on the outer surface of the body.

Aphids (*a*-fuds). Small species of insects that are sometimes called "plant lice."

Aquatic (uh-*quat*-ik). Organisms that live in the water.

Arachnid (uh-*rack*-nid). Member of an animal group that includes the centipedes, scorpions, spiders, and ticks.

Artery (*ar*-ter-ee). A blood vessel which carries blood away from the heart.

Arthropod (*ar*-thro-*pod*). Member of an animal group that includes arachnids, insects, and crustaceans.

Asexual (*a*-sex-uall). Reproduction without the formation of sex cells.

Atoms. Tiny units of which the elements are composed.

Auditory nerves. Nerves which connect the human inner ear with the brain.

Auricle (*aw*-rih-k'l). A heart chamber which receives incoming blood.

Axon. Long, slender process of a nerve cell. Same thing as a nerve fiber.

Bacilli (buh-*sill*-eye). Bacteria that are rodlike in shape. The singular is *bacillus.*

Bacteria (bak-*tih*-ree-uh). Single-celled organisms that are often parasites or saprophytes and lack organized nuclei.

Barriers. Structures, forces, and conditions which tend to limit various species to certain areas. The sea which surrounds an island community, and the pressure which exists in the deep sea are examples.

Beri-beri (*berry-berry*). A vitamin deficiency disease caused by a lack of thiamin.

Biennial (by-*enn*-ih-ul). A plant that completes its life cycle in two growing seasons.

Bird. Member of a group of warm-blooded, feathered vertebrates.

Bladder. Holds and discharges liquid wastes.

Blastula (*blas*-tue-*luh*). Stage in the development of an animal in which the new individual consists of a hollow ball of cells.

Botulism (*bott*-you-lism). A very dangerous type of food poisoning.

Bronchus (*bron*-kus). In man, the trachea branches to form two bronchi. One bronchus then goes to each lung.

Calorie (*kal*-or-ee). A unit used to describe the energy values of foods.

Cambium (*kam*-bee-um). An actively growing layer of one type of plant stem. Associated with it are the phloem and xylem ducts.

Canine teeth. Long, pointed teeth used in grasping prey.

Capillary (*kap*-ul-aree). Tiny, thin-walled type of blood vessel.

Carbohydrates (*kahr*-boh-*hy*-drayts). Compounds of protoplasm such as the sugars and starches.

Carnivores (*kahr*-nuh-vors). Animals that feed largely on the flesh of other animals.

Carotene (*karo*-teen). A yellow plant pigment which becomes changed into vitamin A in the bodies of man and some other animals.

Cartilage (*kahr*-ti-lij). A skeleton tissue, which is partially replaced by bone in some adult animals.

Castes. Special groups of individuals, such as the workers and soldiers found among termites and ants.

Catalase (*kata*-lase). An enzyme found in protoplasm.

Cell membrane. A thin living membrane which surrounds the cytoplasm of a cell.

Cells. Units of structure in both plants and animals.

Cerebellum (*ser*-uh-*bell*-um). A region of the brain in higher animals. In man it coordinates muscular activities and balance.

Cerebrum (*seh*-ruh-brum). A region of the brain in higher animals. In man, the center for memory and intelligence.

Chemosynthesis (*kem*-oh-*sin*-theh-sus). A special food-making process carried on by certain types of bacteria.

Chitin (*ki*-tin). A horny material that forms the outer covering of insects and some other animals.

Chlorophyll (*klor*-roh-fill). A green-colored pigment found in certain plant cells.

Chloroplasts (*klor*-roh-plasts). Chlorophyll-bearing structures in the cytoplasms of certain plant cells.

Chromosomes (*kroh*-moh-sohms). Structures in the nucleus that contain the genes.

Chymotrypsin (*kymo*-trip-sun). A protein-digesting enzyme of the human pancreas.

Cilia (*sih*-lee-uh). Short, threadlike extensions of the cytoplasm that are developed by some cells.

Class. A classification group that includes related orders of plants or animals.

Clay. A very fine-grained soil that is produced when the rocks known as feldspar break down.

Climax community. A group of populations that can maintain themselves over a long period of time.

Club moss. A member of one group of vascular plants.

Cocci (*kok*-eye). Bacteria that are spherical in shape. The singular is *coccus*.

Cochlea (*kok*-lee-uh). Structure of human inner ear which is sensitive to sound waves.

Coelenterates (soh-*len*-terr-ates). Phylum which includes the corals, sea anemones, and jellyfish.

Cold-blooded. Having a blood temperature that varies in response to changes in the temperature of the environment.

Commensals (comm-*enn*-suls). Members of two species that are associated in some way. Neither member of the pair is injured by the association, and one member of the pair may profit to some extent.

Community. A group of plant and animal populations living within some sort of natural boundaries, such as the populations that are found in a freshwater pond.

Compounds. Substances formed through the chemical union of two or more elements.

Conjugate (*conn*-juh-gate). To pass cellular materials from one cell to another, as in *Spirogyra* or *Paramecium*. A primitive type of sexual process.

Control. The factor in an experiment that does not change.

Corium Inner layer of the human skin.

Cornea (*kor*-nee-uh). Transparent covering of human eye, lying in front of the iris and pupil.

Crustacean (krus-*tay*-shun). Member of the arthropod group which includes crabs, crayfishes, and lobsters.

Cyst (*sist*). Protective covering which is secreted around certain small and relatively simple organisms.

Cytoplasm (*sy*-toh-plazm). The outer, more fluid portion of a cell's protoplasm.

Dendrite (*den*-dryt). Process of a nerve cell which receives incoming messages.

Dentine (*den*-teen). The bulk of the tooth above the gum line.

Diabetes (*dy*-uh-*bee*-tez). Disease due to insufficient amount of insulin in the bloodstream.

Diaphragm (*dia*-fram). A muscular structure which separates the thorax from the abdomen in man and other mammals.

Dicot (*die*-kot). A flowering plant that develops two seed leaves.

Dispersal. Process in which a species extends its range beyond its homeland.

Dorsal. Back or upper surface of an animal's body.

Duodenum (duo-*deh*-num). In man, the first loop of the small intestine.

Eardrum. Structure stretched across middle ear which vibrates when sound waves strike it.

Echinoderms (ee-*ky*-nuh-*derms*). Phylum which includes sand dollars, sea lilies, sea cucumbers, starfishes, and sea urchins.

Ecology (e-*kohl*-uh-*jee*). The relationships of organisms to their environments.

Ectoderm (*ekto*-derm). The outer basic cell layer of an animal embryo.

Egg cell. A female sex cell.

Emigrate (*emuh*-grate). To move from one place to another place without a return journey.

Enamel. The hard covering of the tooth above the gum line.

Endoderm (*endo*-derm). The inner basic cell layer of an animal embryo.

Energy. The capacity to do work.

Environment (enn-*vih*-run-munt). Includes all the things and forces that surround the individual at any given time.

Enzymes (*en*-zymes). Proteins which accelerate chemical changes in protoplasm.

Epidemic (epa-*dem*-ick). Condition which exists when many people in the

community contract a disease at about the same time.

Epidermis (epuh-*dermis*). Outer layer of the human skin.

Erepsin (ee-*rep*-sun). A group of protein-digesting enzymes in the intestinal fluid of man.

Erosion (ee-*roh*-zhun). The wearing away of land areas by natural agencies, such as running water and winds.

Esophagus (uh-*sof*-uh-gus). Portion of the human digestive canal which conveys food from the pharynx to the stomach.

Eustachian (you-*stay*-shun) **tube.** Tube which connects the middle ear with the pharynx in man.

Excretion (eks-*kree*-shun). The process by which organisms dispose of their wastes.

Family. A classification group that is made up of related genera.

Fats. Compounds of protoplasm that include the animal fats and plant oils.

Fertilization (*fer*-til-uh-*zay*-shun). Process in which a mature male sex cell unites with a mature female sex cell.

Fission (*fish*-un). Simple type of cell division.

Flagellae (fla-*gell*-ee). Long, threadlike extensions of the cytoplasm that are developed by some cells.

Flatworm. Member of an invertebrate phylum of worms that includes the tapeworms and flukes.

Fungi (*fun*-jye). A group of plants, as well as certain protists, that are without chlorophyll.

Ganglion (*gang*-lee-un). A mass of nerve cells and supporting cells that acts as a control center.

Gastric (*gas*-trik) **juice.** A digestive fluid secreted by glands in the stomach wall.

Gastrula (*gahs*-truh-*luh*). Stage in animal development in which ectoderm and endoderm layers have been formed.

Genes (*jeens*). Small units in chromosomes that contain protein and DNA molecules. Hereditary characters are conveyed by the genes.

Genus (*jee*-nus). A classification group made up of related species.

Germ. A microorganism that can cause a disease. Also known as a *microbe.*

Glucose (*gloo*-kose). One of the simple sugars.

Glycerol. An end-product of fat digestion.

Glycogen (*gli*-koh-gen). A storage form of simple sugar in the human body.

Gravel. Soil composed of fairly large rock particles.

Ground water. Water that is contained in rocks and soils near the earth's surface.

Habitat (*haba*-tat). The type of environment in which a given species normally lives.

Heart muscle. Cardiac muscle cells with cross striations; some of them contain more than one nucleus.

Hemoglobin (*hee*-moh-*glo*-bin). A red-colored protein found in red corpuscles.

Hemophilia (*hee*-moh-*feel*-ee-uh). Bleeding disease in which the blood does not clot normally.

Herbivores (*her*-buh-vors). Animals that feed largely or wholly upon plant materials.

Heredity. The process in which characters are passed from generation to generation.

Hibernate (*hyber*-nayt). To go into a torpid condition, in which the life processes continue but at a reduced rate.

Holdfast. Structure which serves to attach some simple plants to solid objects in the water.

Hormones (*hor*-moans). "Chemical messengers" secreted by ductless glands.

Horsetail. A member of one group of vascular plants.

Host. A plant or animal that supports a parasite.

Humerus. Bone of the upper arm in man and various other vertebrates.

Hybrid (*hy*-brid). An individual which

has opposed genes for one or more characters.

Hypha (*hy*-fuh). Branching structure of a mold plant. Such a plant has three general types of hyphae: stolons, rhizoids, and upright hyphae that bear spore cases.

Immunity (imm-*yoon*-uh-tee). Condition in which the individual is more or less protected against a disease, due to the presence of antibodies in his blood plasma.

Incisor (in-*cizor*). Type of front tooth which is large and adapted for gnawing in rats, woodchucks, and other rodents.

Individual variation. The fact that no two members of a species are identical.

Infection (in-*fek*-shun). Condition in which enough germs are present to produce the symptoms of a disease.

Insect. An arthropod that may or may not have wings, but has six walking legs at some stage in its life cycle.

Insulin (*in*-suh-lun). A hormone secreted by certain cells of the human pancreas.

Invertebrate (in-*ver*-tuh-*brate*). An animal which does not develop a backbone.

Iris (*eye*-rus). Colored portion of the human eye, as seen from the exterior. The pupil is in its center.

Isotope (*iso*-tope). Atoms of the same element which differ from each other in atomic weight.

Lactose (*lak*-tose). A carbohydrate-digesting enzyme of the human intestinal fluid.

Lamprey (*lam*-pry). A fishlike animal, which lacks the functional jaws and bony skeleton of the bony fishes.

Larva (*lar*-vuh). An early stage in the life cycle of some animals.

Larynx (*lahr*-incks). Air chamber between the pharynx and the trachea, which contains the human vocal cords.

Lens. Transparent disc by means of which light rays are directed to the retina.

Lichen (*li*-ken). A type of plant growth that consists of an alga and a fungus that live together.

Life cycle. The course of life in a plant or animal. Usually includes periods of youth, maturity, and old age.

Ligaments (*lig*-a-munts). Strong bands of connective tissue which hold bones together at the joints.

Lipase (*lie*-pase). A fat-splitting enzyme secreted by glands of the pancreas.

Loam. Soil which represents a mixture of gravel, sand, clay, and silt.

Lymph (*limf*). The fluid found in lymph vessels. Similar to blood plasma.

Maltose (*mol*-tose). A carbohydrate-digesting enzyme of the intestinal fluid.

Mammal (*mam*-m'l). Member of a group of haired vertebrates.

Marrow. Substance which fills the central cavities of long bones in some higher animals.

Mass selection. The age-old practice of using the "best" plants and animals to produce the next generation.

Matter. The solids, liquids, and gases that make up our world.

Medulla (muh-*duhl*-uh). A region of the brain in higher animals. It connects the rest of the brain with the spinal cord.

Meiosis (mee-*oh*-sus). Cell division in which there is a reduction of chromosomes during the formation of egg and sperm cells.

Mesoderm (*messo*-derm). The middle basic cell layer developed by some animals.

Migrate (*my*-grate). To engage in a two-way journey, as between a winter home and a summer home.

Mimicry (*mimi*-kree). Resemblance to some object in both form and color. Protects organisms from natural enemies.

Mitosis (my-*toh*-sus). Cell division in which the chromosomes are equally divided between two daughter cells.

Molecule (*mol*-uh-*kule*). The smallest unit of a compound.

Mollusk (*moll*-usk). Member of an invertebrate phylum that includes snails, clams, and oysters.

Monocot (*mono*-kot). A flowering plant that develops a single seed leaf.

Mutualism (*mew*-tew-uh-lizm). An association between two species, in which the members of both species profit.

Narcotic (nahr-*kott*-ik). A type of drug used in medicines to dull pain, but some of the narcotic drugs are habit-forming.

Neuron. A nerve cell.

Niacin (*ni*-uh-sun). A "B complex" vitamin which prevents development of the disease pellagra.

Nitrogen cycle. A natural cycle in which nitrogen molecules go from the air to nitrates, to plant proteins, to animal proteins, to decay products, and back to the air again.

Nitrogen-fixing bacteria. Certain bacteria that are able to use free nitrogen in making nitrates.

Nocturnal (nock-*tur*-nul). Active during the hours of darkness, rather than by day.

Nucleic acids (new-*klee*-ick). The *DNA* and *RNA* that are so active in the lives of cells.

Nucleoproteins (*new*-kleo-*proh*-teeuns). Giant protein molecules that sometimes have the ability to reproduce themselves.

Nucleus (*new*-klee-us). An organized control center in many types of cells.

Nymph (*nimf*). An early stage in the life cycle of certain animals, such as the grasshoppers.

Omnivores (*om*-nuh-vors). Animals that eat a variety of materials from both plant and animal sources.

Optic (*op*-tik) **nerves.** A pair of nerves which connect the eyes with the brain.

Order. A classification group consisting of related families.

Organ. Structure consisting of tissues which carry out a certain function or more than one function.

Organism (*or*-gan-*izm*). Any plant or animal.

Osmosis (oz-*moh*-sus). The process in which molecules pass through a semipermeable membrane.

Ovary (*oh*-vah-ree). A female sex organ.

Oxidation (*oks*-suh-*da*-shun). A chemical change in which a substance combines with oxygen.

Pellagra (puh-*lay*-gruh). Vitamin deficiency disease caused by a lack of niacin.

Pancreas (*pan*-kree-us). In man, a flattened, light-colored gland lying in the loop formed by the duodenum.

Parasites (*pahr*-uh-sytes). Organisms that live at the expense of other plants and animals.

Pasteurized (*pass*-teur-ized). Heated enough to kill dangerous germs, but not enough to alter its original nature to any great extent.

Pellicle (*pell*-ik-ul). The outer covering of some animal cells.

Pepsin (*pep*-sun). An enzyme of the human stomach glands which acts upon proteins.

Perennial (per-*enn*-ee-ul). A plant whose life cycle extends through several and sometimes many growing seasons.

Petals (*pet*-uls). The brightly-colored parts of many flowers.

Pharynx (*fahr*-incks). In some animals this is a part of the digestive canal immediately behind the mouth cavity.

Phloem (*flow*-em). Groups of ducts in certain plant stems that serve to conduct foods.

Photosynthesis (*foh*-toh-*sin*-theh-sus). A type of food manufacture carried on by green plants and a few types of bacteria.

Phylum (*fy*-lum). A classification group consisting of related classes.

Pistils (*pis*-tuls). The female structures of some flowers.

Pituitary (puh-*two*-uh-*tary*). Two-lobed ductless gland attached to the base of the human brain.

Placenta (pluh-*sen*-tuh). Special structure developed by many female mammals for the nourishment of the young.

Plankton (*plank*-tun). Masses of small, simple plants and animals that float at or

near the water surface. Found in both fresh waters and the seas.

Plasma (*plaz*-muh). A basic fluid of blood in man and many other animals.

Platelets (*plait*-luts). Very small bodies found in the plasma which aid in blood clotting.

Pollen grains. Male sex products produced by the anthers of flowers.

Pollination (*pahl*-uh-*nay*-shun). The transfer of pollen grains from an anther to a stigma.

Population. A group of individuals of the same species living in a community.

Porifera. Phylum which includes the sponges.

Protective coloration. Any coloration which makes the organism less likely to be seen by its natural enemies.

Proteins (*proh*-tee-uns). Compounds of protoplasm that contain carbon, hydrogen, oxygen, and nitrogen.

Protists (*proh*-tists). The third kingdom which includes simple borderline organisms.

Protonema (*proh*-toh-*nee*-muh). Branching structure from which a young moss plant develops.

Protoplasm (*pro*-toh-plazm). The living substance.

Protozoa (*proh*-toh-*zoh*-uh). A phylum of relatively simple organisms, now classified as protists.

Ptomaines (*toe*-mains). Substances from the decay of proteins that cause food poisoning.

Ptyalin (*tie*-al-in). A starch-digesting enzyme of human saliva.

Puberty (*pu*-ber-tee). A period of adolescent development when there are great emotional and physical changes.

Pulp cavity. Area within the root of the tooth through which nerves and blood vessels pass to the interior of the tooth.

Pupa (*pew*-puh). A stage in the life cycle of some insects, during which the organism develops into an adult.

Pupil. The opening in front of the eyeball, the size of which is controlled by the iris.

Radioactive (radio-*ak*-tiv). A substance that gives off radiation in the form of energy or atomic particles.

Radius. Bone of the forearm in man and various other vertebrates.

Red corpuscle (*kor*-pusl). An oxygen-carrying cell found in the blood of man and various other higher animals.

Reduction division. Process in which a sex cell loses half of its chromosome content as it becomes mature.

Regeneration (ree-*jenner*-ashun). The production of new parts to replace parts that have been destroyed.

Rennin (*renn*-un). An enzyme of the human stomach glands, which acts upon proteins.

Reproduction (ree-pro-*duck*-shun). The process in which new individuals of a species are brought into being.

Reptile (*rep*-til). A cold-blooded vertebrate such as a crocodile, turtle, or snake.

Retina (*ret*-nuh). Layer in eyeball whose cells are sensitive to light rays.

Rhizoid (*ri*-zoid). One type of mold hypha that extends down into the bread surface.

Rickets. Deficiency disease due to lack of vitamin D.

Roundworm. Member of an invertebrate phylum of worms that are unsegmented.

Saliva. A fluid secreted into the mouth by the salivary glands.

Sand. Soil composed largely of fairly small rock particles.

Saprophytes (*sap*-roh-phyts). Organisms that feed upon plant and animal materials that are dead and decaying.

Scion (*si*-un). Stem or bud with desired characters that is grafted on a rootstock.

Scurvy. Deficiency disease caused by a lack of vitamin C.

Segmented worm. Member of an invertebrate phylum that includes the earthworms and leeches.

Semicircular canals. Organs of balance in the human ears.

Sepals (*see*-puls). Structures around

the base of a flower. Often green and leaflike.

Setae (*set*-tee). Bristlelike structures developed by some segmented worms, such as the earthworms.

Sex chromosomes. Special chromosomes that have to do with sex determination.

Silt. A fine-grained soil that has been deposited after being suspended in water.

Smooth muscle. Type of muscle tissue found in the skin layer and the walls of internal organs. An involuntary type of muscle.

Somatic (soh-*mattik*) **cells.** All the cells of an organism's body except the sex cells.

Species (*spee*-sheez). The particular kind of plant or animal.

Sperm cell. A male sex cell.

Spirilla (spy-*rill*-uh). Bacteria that have a spiral form. The singular is *spirillum.*

Spongin (*spun*-gin). Material that forms the skeletons of some sponges.

Spore. Small cell, which in some cases is able to develop into a new individual.

Stamens (*stay*-muns). The male structures found in some flowers.

Stigma (*stigg*-muh). Structure at the upper end of a pistil in a flower.

Stimulus. Any force which acts upon an organism so as to produce a response.

Stock. Rooted portion of a plant upon which a scion is grafted.

Stolon (*stow*-lun). One type of mold hypha that spreads out on the surface.

Stomata (stow-*mah*-tuh). Tiny pores on the surfaces of leaves, through which gases enter or escape.

Striated muscle. Type of muscle tissue found in voluntary muscles.

Subsoil. The layer of soil beneath the topsoil, which extends on downward to bed rock.

Succession. A series of changes in the population of a community, sometimes leading to the development of a fairly stable climax community.

Sucrose (*soo*-krose). A carbohydrate-digesting enzyme of the human intestinal fluid.

System. A group of organs, as in the case of a digestive system, that carry out a general function.

Tendons (*ten*-duns). Connective tissue structures at the ends of voluntary muscles. They attach the muscles to bones or to other muscles.

Testes (*tes*-teez). Male sex organs.

Thallus (*thal*-luss). Body structure of certain simple plants, such as the rockweeds.

Thiamin (*thigh*-uh-mun). Vitamin B_1, which prevents development of the disease beri-beri.

Thorax (*thor*-acks). A mid region of various animal bodies. In man it contains the heart and the lungs.

Thyroid gland. Two-lobed ductless gland of man, located in the neck region.

Thyroxin (thigh-*rocks*-sun). Hormone secreted by the human thyroid gland.

Tissue. A structure made up of similar cells, all of them performing the same general functions.

Tissue fluid. In man, fluid that has escaped from blood vessels to mingle with the cells of the body tissues.

Topsoil. The upper or surface layer of soil, which usually contains most of the decay products that come from dead plants and animals.

Trachea (*tray*-kee-uh). In man, a passageway for air going to and from the lungs. Connects the larynx with the bronchi.

Transpiration (*tranz*-per-*ray*-shun). Process by which plants lose water vapor to the air.

Tree line. The level on a high mountain side above which no trees grow. In the Arctic, the northern limit of tree growth.

Trichocysts (*trick*-o-sists). Special defense structures developed by a *paramecium.*

Trypsin (*trip*-sun). A protein-digesting enzyme of the human pancreas.

Tuber (*too*-ber). Fleshy enlargement of an underground stem, as in the case of white potatoes.

Tubules. Kidney structures that remove wastes from the blood.

Tumor. Lumplike overgrowth of cells in some tissue.

Ulna (*ul*-nuh). Bone of the forearm in man and various other vertebrates.

Umbilical (um-*billik*-ul) **cord.** Structure which connects a developing mammal with its placenta.

Urea (*eu*-ree-uh). In man, a protein waste compound that is produced in the liver.

Ureter (eu-*ree*-ter). In man, a tube extending from a kidney to the bladder.

Urethra (eu-*reeth*-ruh). In man, the tube through which the bladder drains to the exterior.

Urine (*yoo*-run). The liquid waste substance discharged by the kidneys.

Uterus (*you*-ter-us). Reproductive structure of a female mammal. The young undergo development in the uterus.

Vacuoles (*vack*-voo-oles). Spaces scattered throughout the cytoplasm of the cell.

Vaccination (*vak*-suh-*nay*-shun). The use of cowpox vaccine to render people immune to smallpox.

Vaccine (vak-*seen*). A substance used to produce immunity to a given disease.

Variation (*vair*-ee-*ay*-shun). The fact that individuals of a species differ from one another.

Vein. A blood vessel which carries blood toward the heart.

Ventricle (*ven*-trih-k'l). A heart chamber which pumps blood out of the heart.

Vertebrae (*ver*-tuh-bree). The bones that make up the backbone of a vertebrate.

Vertebrate (*ver*-tuh-brate). An animal that develops a backbone.

Villi (*vill*-eye). Fingerlike projections on the lining of the human small intestine.

Virus (*vy*-rus). Consists of viral particles which exhibit some of the characteristics of living things. Parasitic upon plant or animal cells.

Vitamins (*vy*-tuh-mins). Substances present in foods or formed in animal bodies which prevent the development of deficiency diseases.

Warm-blooded. Having a blood temperature that may vary through a daily cycle, but without reference to temperature variation of the environment.

Water table. The upper level at which ground water saturates the soil and rocks.

White corpuscle (*kor*-pusl). Ameboid type of cell found in the blood of man and various other higher animals.

Xylem (*zy*-lem). Groups of ducts in certain plant stems that conduct water.

Zygote (*zi*-gote). Cell which results when a male sex cell and a female sex cell unite.

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